

666

~~21256~~

21277-1



Sonderforschungsbereich 313

VERÄNDERUNGEN DER UMWELT: DER NÖRDLICHE NORDATLANTIK

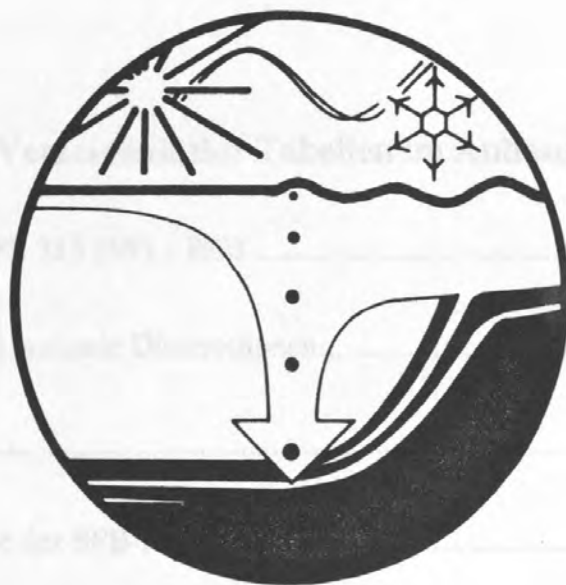
BERICHTSBAND 91-92-93

BAND 2

PUBLIKATIONEN UND MANUSKRIPTE

Christian-
Albrechts-
Universität
zu Kiel,
im Mai 1993





Sonderforschungsbereich 313

VERÄNDERUNGEN DER UMWELT: DER NÖRDLICHE NORDATLANTIK

BERICHTSBAND 91-92-93

BAND 2

PUBLIKATIONEN UND MANUSKRIPTE

Christian-
Albrechts-
Universität
zu Kiel,
im Mai 1993



Verzeichnis der Tabellen im Anhang

Expeditionen des SFB 313 1991 - 1993	Anhang S. 1
Abgeschlossene und laufende Dissertationen.....	Anhang S. 2
Gastforscher	Anhang S. 5
Vorträge im Rahmen des SFB-Kolloquiums	Anhang S. 6
Programm des Berichtskolloquiums November 1992	Anhang S. 10
Verzeichnis der SFB-Berichte	Anhang S. 14
Verzeichnis der SFB-Publikationen	Anhang S. 19
Kurzfassungen von Veröffentlichungen und Manuskripten	Anhang S. 39

Expeditionen im Rahmen des SFB 313: 1991-1993

<u>Zeitraum</u>	<u>Fahrtleiter</u>	<u>Expedition</u>	<u>Teilprojekte</u>
1991			
18.02. - 20.03.	J. Rumohr	POSEIDON 181	<u>A2</u> , B3
15.07. - 08.08.	A. Altenbach	METEOR 17/1	A1, A2, A3, A4, <u>B2</u> , B3
08.08. - 31.08.	E. Suess	METEOR 17/2	<u>A4</u> , B1, B2, B3
16.05. - 03.06.	J. Mienert	VALDIVIA 112	A1, <u>B1</u> , B4
1992			
05.06. - 28.06.	R. Henrich	METEOR 21/4	<u>A2</u> , B3, A3, B1
29.06. - 24.07.	G. Graf	METEOR 21/5	A1, <u>A3</u> , A4, B1, B2, B3
20.08. - 17.09.	J. Mienert	LIVONIA	<u>B1</u>
12.10. - 29.10.	J. Rumohr	POSEIDON 196	<u>A2</u>

Abgeschlossene Dissertationen 1991-1993**TP A1**

Voß, Maren: Räumliche und zeitliche Verteilung stabiler Isotope ($\Delta 15\text{ N}$, $\Delta 13\text{ C}$) in suspendierten und sedimentierten Partikeln im Nördlichen Nordatlantik.

TP A2

Blaume, Frank: Hochakkumulationsgebiete am norwegischen Kontinentalhang: Sedimentologische Abbilder Topographie-geführter Strömungsmuster.

Wagner, Thomas: Organisches Material in pelagischen Sedimenten: Glaziale/Interglaziale Variationen im Europäischen Nordmeer.

TP A3

Thies, Andrea: Die Benthos-Foraminiferen im Europäischen Nordmeer.

Thomsen, Laurenz: Untersuchungen zur Bodennepheloidschicht am westlichen Barents See Kontinentalhang.

TP A4

Köster, Marion: Mikrobieller Abbau von organischem Material an Grenzzonen.

Paetsch, Hanno: Sedimentation im Europäischen Nordmeer: Radioisotopische, geochemische und tonmineralogische Untersuchungen spätquartärer Ablagerungen.

TP B2

Bauch, Henning: Planktische Foraminiferen im Europäischen Nordmeer - Ihre Bedeutung für die paläoozeanographische Interpretation während der letzten 600.000 Jahre.

Struck, Ulrich: Zur Paläo-Ökologie benthischer Foraminiferen im Europäischen Nordmeer während der letzten 600.000 Jahre.

Weinelt, Mara: Veränderungen der Oberflächenzirkulation im Europäischen Nordmeer während der letzten 60.000 Jahre - Hinweise aus stabilen Isotopen.

Laufende Dissertationen**TP A1**

Haupt, Olaf: Entwicklung von Modellansätzen zum biologisch medierten Fluß von organischem Kohlenstoff und Stickstoff im Europäischen Nordmeer.

Peeken, Ilka: Modifikation von Marker-Pigmenten im pelagischen Nahrungsnetz des Europäischen Nordmeeres und ihre Abbildung im vertikalen Partikelfluß.

Reitmeier, Sven: Der Einfluß des Mikrozooplanktons auf den Stoffumsatz im Pelagial hoher Breiten.

Richter, Claudio: Saisonale Veränderlichkeit des Zooplanktons in der zentralen Grönlandsee.

Thomsen, Claudia: Verfolgung pelagischer Prozesse mit Hilfe von biochemischen Komponenten am Beispiel der Alkenone (C37:3, C37:2).

Zeller, Ute: Vorkommen und Sekundärproduktion herbivorer Zooplankter im Europäischen Nordmeer.

TP A2

Goldschmidt, Peter: Lithologie von Sedimentkernen der letzten zwei Glazial/Interglazial-Zyklen im Europäischen Nordmeer.

Michels, Klaus: Rekonstruktion mit Hilfe von Sinkgeschwindigkeitsverteilungen der Sandfraktion zur Bilanzierung des vertikalen und lateralen Partikelflusses.

TP A3

Juterzenka, Karen von: Untersuchungen zur Bedeutung von Schlangensteinen (Ophiuroidea, Echinodermata) für den Stoff- und Partikelfluß in der bodennahen Grenzschicht.

Ritzrau, Will: Produktion und Modifikation von Partikeln durch Mikroorganismen in der bodennahen Grenzschicht.

Witte, Ursula: Reproduktion und metabolische Aktivität von Tiefseeschwämmen im nördlichen Nordatlantik.

TP A4

Bussmann, Ingeborg: Untersuchungen zur Verbreitung und Aktivität von methanoxidierenden Bakterien an Methanquellen.

Maaßen, Jörg: Beschreibung von Transportprozessen an Hand von Biomarkern in partikulärem Material

TP B1

Bobsien, Michael: Entwicklung eines hochfrequenten Ozeanbodenseismometers und erste Messungen.

Chi, Jian: Entwicklung eines Multi-Sensor-Core-Loggers - Vermessungen und Interpretationen der erhaltenen Kerndaten.

Hollender, Franz-Josef: Bearbeitung und Interpretation digitaler Parasound-, Seismik- und Seitensicht-Sonardaten.

TP B2

Jung, Simon: Wassermassenaustausch zwischen Norwegisch-Grönländischer See und Nordatlantik im Spätquartär.

Nees, Stefan: Die Reaktion benthischer Foraminiferen auf schnelle Klimawechsel.

TP B3

Andruleit, Harald: Aktuopaläontologische Untersuchungen zu Verbreitung und Vertikalfluß von Coccolithophoriden sowie ihre räumlich-zeitliche Entwicklung im Jungquartär des Europäischen Nordmeeres.

Baumann, Astrid: Aktuopaläontologische Untersuchungen zu Verbreitung und Vertikalfluß von Dinoflagellaten-Zysten sowie ihre räumlich-zeitliche Entwicklung im Jungquartär des Europäischen Nordmeeres.

Kohly, Alexander: Aktuopaläontologische Untersuchungen zu Verbreitung und Vertikalfluß von Diatomeen sowie ihre räumlich-zeitliche Entwicklung im Jungquartär des Europäischen Nordmeeres.

Schröder, A.: Aktuopaläontologische Untersuchungen zu Verbreitung und Vertikalfluß von Radiolarien sowie ihre räumlich-zeitliche Entwicklung im Jungquartär des Europäischen Nordmeeres.

TP B4

Haupt, Bernd: Numerische Modellierung der Paläo-Sedimentation im nördlichen Nordatlantik.

Schäfer-Neth, Christian: Numerische Modellierung der Paläo-Ozeanographie im nördlichen Nordatlantik.

Gastforscher im SFB 313**1991**

Prof. Dr. William Hay 01.01. - 30.06. TP B2
Cooperative Institute for Research
in Environmental Sciences,
University of Colorado, Boulder USA

Prof. Dr. Barry Hargrave 15.03. - 30.04. TP A1
Bedford Institute of
Oceanography, Dartmouth,
Canada

1992

Dr. Xiuming Liu 01.04. - 30.06. TP B1
Geomagnetism Laboratory
University of Liverpool
Liverpool, GB

Prof. Dr. William Hay 01.11. - 31.12. TP B2
Dr. William Ambrose 11.11. - 16.11. TP A3
East Carolina University
Greenville, USA

1993

Prof. Dr. Dan Seidov 01.01. - 30.04. TP B4
Akademie der Wissenschaften
Moskau, GUS

Prof. Dr. Anna Szaniawska 28.03. - 07.04. TP A3
Universität Danzig
Polen

SFB-Kolloquiumsvorträge 1991-1993

05.04.91

Winter, A., Department of Marine Sciences, University of Puerto Rico: Coccolithophores and Global Change.

11.04.91

Hargrave, B., Bedford Institut, Kanada: Biogeochemical Investigations in the Arctic Ocean.

12.04.91

Hargrave, B., Bedford Institut, Kanada: Importance of Basins for Cycling of Organic Matter on Continental Shelves.

19.04.91

Goldschmidt, P., SFB 313: Stammen "Sediment Pellets" aus Meereis oder aus Eisbergen?

26.04.91

Emeis, K., GPI: Pyrolyse-Gaschromatographie und Py-GC-Massenspektroskopie von marinen Sedimenten.

03.05.91

v. Bodungen, B., Rumohr, J., Scholten, J., SFB 313: Erste Ergebnisse der Poseidon-Ausfahrten 173/2 und 181.

17.05.91

Voß, M., SFB 313: Tragen stabile Isotope (^{13}C , ^{15}N) in der organischen Substanz Informationen über pelagische Prozesse?

24.05.91

Matthießen, J., GEOMAR: Organische Mikrofossilien im Spätquartär des Europäischen Nordmeeres.

31.05.91

Piepenburg, D., IPÖ: Benthische Besiedlungsmuster in arktischen Meeresgebieten - Ergebnisse und Perspektiven der Untersuchungen des Instituts für Polarökologie.

07.06.91

Thomsen, C., Schulz, D., SFB 313: Erste Ergebnisse der Biomarker-Untersuchungen der Meteor Ausfahrt 13/2.

14.06.91

Thomsen, L., Linke, P., Graf, G., SFB 313: Flüsse zwischen Bodennepheloidschicht und Sediment - erste Ergebnisse vom Bäreninselprofil der Sommer- und Winterexpedition M13 und P181.

21.06.91

Karpuz, N., Geologisches Institut der Universität Bergen: Surface sediment diatom distribution and Holocene paleotemperature variations in the Gin-Sea.

28.06.91

Henrich, R., GEOMAR: Erste geologische Ergebnisse der Polarstern-Ausfahrt VII/1.

Wagner, T., SFB 313: Organische Substanzen in glazial/interglazialen Ablagerungen aus dem Europäischen Nordmeer, Vöring Plateau.

05.07.91

Mienert, J., Preuß, H., Bobsien, M., Chi, J., SFB 313: Vorstellung der Arbeitsgruppe aus dem TP B1: Bearbeitung von hochfrequenten akustischen Daten und ihre Anwendung in der Paläoozeanographie.

12.07.91

Fabry, V., International Laboratory of Marine Radioactivity, Monaco: Aragonite Fluxes and stable isotopic composition of shelled Pteropods in the Sargasso Sea.

26.08.91

Fry, B., MBL Woods Hole, USA: DOC metabolism in a salt-marsh estuary.

04.10.91

Seidov, D., Akademie der Wissenschaften Moskau: Numerical modelling in the field of physical paleoceanography (modelling of the ocean paleocirculation).

11.11.91

Hüttel, M., IPÖ: Bioturbation, Biorauhigkeit und Nischenbildung in marinen Weichböden.

13.12.91

Reitner, J., FU Berlin: Benthos-Zonierungen der Vesterisbanken-See (NE-Grönland-See).

14.02.92

Koeve, W., IfM: Why care about New Production?

28.02.92

Ritzrau, W., SFB 313: Einfluß von Resuspension und Turbulenz auf Bakterien.

06.03.92

Thomsen, L., SFB 313: Bodennepheloid-Charakteristika am westlichen Barentssee-Kontinentalhang.

13.03.92

Scholten, J., SFB 313: Radionuklide in Sedimenten: Tracer für Partikelfluß und Verweilzeiten von Wassermassen!?

20.03.92

Gerlach, S.A., IfM: Größenspektren und Bioturbationspotential der Makrofauna auf dem Vöring-Plateau.

27.03.92

Haupt, B., Schäfer-Neth, C., SFB 313: Drei- und eindimensionale Modelle der Zirkulation und Sedimentation im Europäischen Nordmeer - Stand der Dinge im TP B4.

03.04.92

Thiede, J., GEOMAR: Die ARKTIS 91 Expedition.

10.04.92

- Bauch, H., SFB 313: Paläo-ozeanographische Bedeutung subpolarer Fauna in der Termination II.
08.05.92
- Weinelt, M., SFB 313: Schmelzwasserpulse im Nordmeer - zeitliche und räumliche Verteilung.
15.05.92
- Ramseier, R., AWI Bremerhaven: Fernerkundung von Meereseis mit Mikrowellen.
22.05.92
- Liu, X., University of Liverpool: Rockmagnetic properties of Chinese loess and its paleoclimatic significance.
13./14.11.92
- Berichtskolloquium des SFB 313
30.11.92
- Eisenhauer, A., Heidelberg: Rekonstruktion holozäner Meeresspiegel-Schwankungen aus U/Th (TIMS) und 14C (AMS)-Datierungen an Korallen von den Abrolhos-Inseln (W-Australien).
11.12.92
- Thomm, M., Inst. f. allm. Mikrobiologie: Archäobakterien: Stoffwechsel und ihr Beitrag zum Kreislauf des Schwefels und Kohlenstoffs in marinen Hydrothermalsystemen und Sedimenten.
18.12.92
- Hay, W., GEOMAR: Wasserbilanz der Arktis während der letzten Vergletscherung und während des Eisrückganges.
15.01.93
- Gradinger, R., IPÖ: Die Biologie im Eisrandbereich.
22.01.93
- Rumohr, J., GEOMAR: Der ostgrönländische Küstenstrom fließt im Sommer nach Norden.
29.01.93
- Fu, S., GPI: Lebensspuren als paläo-ozeanographische Indikatoren: ein Beispiel vom Island-Färöer-Rücken.
05.03.93
- Michels, K., SFB 313: Korngrößenbetrachtungen zum Sedimenttransport.
Locker, S., SFB 313: Plankton und Tephraereignisse während der letzten Deglaziation in der Norwegischen See.
12.03.93
- von Juterzenka, K., SFB 313: Schlangensterne im Europäischen Nordmeer - welche Rolle spielen sie für Stoffumsatz und Partikeltransport.
Ritzrau, W., SFB 313: Northeast water polynia 92 - Erste Ergebnisse

19.03.93

Haupt, O., SFB 313: Ökosystemmodelle im Europäischen Nordmeer.

Struck, U. SFB 313: Was erzählen uns die benthischen Foraminiferen über Paläo-Ökologie und Paläo-Ozeanographie

26.03.93

Blaume, F., SFB 313: Advektion in der Norwegischen See.

31.03.93

Stein, R., AWI Bremerhaven: Sedimentationsprozesse und Paläoozeanographie am ostgrönländischen Kontinentalhang - Laufende und geplante Untersuchungen am AWI

02.04.93

Thomsen, C., SFB 313: Verfolgung pelagischer Prozesse mit Hilfe von biochemischen Komponenten am Beispiel der Alkenone (C37:3, C37:2).

Nees, S., SFB 313: Das Abbild dynamisch klimatischer Prozesse in der benthischen Foraminiferen-Fauna.

07.05.93

Reitmeier, S., SFB 313: Einfluß des Mikrozooplanktons auf den Stoffumsatz im Pelagial hoher Breiten.

14.05.93

Hollender, F.-J., SFB 313: Untersuchungen des ostgrönländischen Kontinentalhangs mit dem Weitwinkel-Seitensicht-Sonar "GLORIA".

28.05.93

Schröder, A., Kohly, A., SFB 313: Sedimentation kieseliger Planktonorganismen im Europäischen Nordmeer: Ein Vergleich aus Sinkstoffallen der Grönlandsee und der Norwegensee.

BERICHTSKOLLOQUIUM AM 13. UND 14. NOVEMBER 1992 IN KIEL

Ort: Institut für Meereskunde (Hörsaal), Düsternbrooker Weg 20

P R O G R A M M

Freitag, den 13. November 1992

9.00 - 9.15 Uhr - Begrüßung durch den
Dekan der Mathem.-Naturwiss. Fakultät
und die Sprecherin des SFB 313

BLOCK I: "PARTIKELBILDUNG, -MODIFIKATION UND -SEDIMENTATION:
REZENT UND FOSSIL"

9.15 - 11.45 Uhr - Vorträge

P. Wassmann: Pelagic-benthic coupling and advection in the
(Tromsø) Barents Sea. (30 min)

D. Hebbeln: Einfluß der Eisbedeckung auf die rezente und
(Bremen) die spätquartäre Sedimentation in der Fram-
Straße. (20 min)

E. Bauerfeind: Pelagische Systeme und Sedimentationsmuster: Ein
Vergleich Grönländische See - Norwegische See.
(20 Min)

D. Schulz-Bull: Biomarker im partikulären Material aus dem
nördlichen Nordatlantik. (20 min)

A. Schröder: Über die Komplexität der Planktongemeinschaften
in der Wassersäule und ihrem Abbild im Sediment
- Kritische Betrachtung an vier ausgewählten
Planktongruppen. (20 min)

A. Kohly: Diatomeen- und Radiolarien-Flux in der Grönland-
see - Vergleich der Arten-Assoziationen in der
Wassersäule und im Sediment. (15 min)

11.45 - 12.45 Uhr - Postersession mit Kaffee
(Konferenzraum)

12.45 - 14.00 Uhr - Mittagessen (Restaurant Seeburg)

BLOCK II: "PROZESSE UND BILANZEN DES BODENNAHEN
SEDIMENTTRANSPORTES"

14.00 - 16.30 Uhr - Vorträge

- J. Meincke: Die Rolle des Europäischen Nordmeeres im
(Hamburg) Klimasystem. (20 min)
- J. Jungclaus: Zirkulation, Tiefenwasserbildung und Ausbreitung
(Hamburg) auf dem Barentssee-Schelf. (20 min)
- F. Blaume: Topographisch-gesteuerte Sedimenttransport-
prozesse in hohen Breiten. (20 min)
- J. Rumohr: Sedimentologische Dokumentation topographisch-
gesteuerter Sedimenttransportprozesse in hohen
Breiten. (20 min)
- T. Wagner: Organisches Material in glazial/interglazialen
Ablagerungen des Europäischen Nordmeeres.
(20 min)
- J. Scholten: Einfluß des lateralen Sedimenttransportes auf
die Sedimentakkumulation in der Norwegischen See
während der letzten 300.000 Jahre: Bilanzierung
aufgrund des ^{230}Th -Flusses. (20 min)
- F.-J. Hollender: Untersuchung des Meeresbodens und seiner
sedimentphysikalischen Eigenschaften mit Hilfe
der Analyse von akustischen Signalen (GLORIA,
Parasound). (20 min)
- J. Mienert: Zur holozänen Entwicklung des ostgrönländischen
Kontinentalhanges. (20 min)

Abschließende Diskussion

16.30 - 18.00 Uhr - Postersession mit Kaffee

Anschließend: gemeinsames Abendessen in der "Forstbaumschule"

Sonnabend, den 14. November 1992

BLOCK III: "BENTHISCHE BESIEDLUNGSMUSTER UND ABBAUPROZESSE:
REZENT UND FOSSIL"

9.00 - 11.30 - Vorträge

- W. Ambrose: Benthic processes in the new water polynya.
(Greenville/USA) (25 min)
- P. Linke: Reaktion einer benthischen Tiefseegemeinschaft
auf einen simulierten Nahrungspuls. (10 min)
- M. Köster: Mikrobieller Abbau und Ablagerung von orga-
nischem Material in Sedimenten der Barentssee.
(10 min)
- H.D. Schulz: Stoff-Umsatzraten in oberflächennahen Sedimenten
(Bremen) des Südatlantik. (25 min)
- L. Thomsen: Untersuchungen zur Boden-nepheloidschicht am
westlichen Barentssee-Kontinentalhang. (10 min)
- D. Piepenburg: Besiedlungsmuster und Lebensformen der
benthischen Makrofauna in Beziehung zur Boden-
nepheloidschicht. (15 min)
- U. Struck: Das Abbild fossiler Foraminiferen-Faunen in
spätquartären Sedimenten. (10 min)

11.30 - 12.30 Uhr - Postersession mit Kaffee
Konferenzraum

12.30 - 14.00 Uhr - Mittagessen (Restaurant Seeburg)

BLOCK IV: "PALÄO-OZEANOGRAPHIE UND PALÄOKLIMA IN VERSCHIEDENEN
ZEITSCHNITTEN"

14.00 - 16.10 Uhr - Vorträge

E. Jansen: Dynamics of ocean circulation changes in the
(Bergen) GIN seas. (20 min)

D. Seidov et al.: Toward a better understanding of the melt-
(Kiel/Moskau) water event near 13.6 ka - A numerical
modelling approach. (15 min)

C. Schäfer-Neth et al.: Strömungsmuster im Nordatlantik, rezent
und letzte Maximalvereisung: Erste Ergebnisse
mit dem SCINNA-Modell. (15 min)

M. Hald: Barents Sea paleoceanography over the past
(Tromsø) 30,000 years. (15 min)

A. Baumann: Raum-zeitliche Verteilung von Planktonzönosen
im Jungquartär des nördlichen Nordatlantik.
(15 min)

16.15 - 17.15 Uhr - Postersession mit Kaffee

17.15 - 17.45 Vortrag

A. Altenbach: Rezente und fossile Verbreitungsmuster
benthischer Foraminiferen im Europäischen
Nordmeer: Abbildung der Dynamik der Ober-
flächenwassermassen. (20 min)

Berichte aus dem Sonderforschungsbereich 313

- 1) Thiede, J., Gerlach, S.A., Wefer G.: Sedimentation im Europäischen Nordmeer, Organisation und Forschungsprogramm des Sonderforschungsbereichs 313 für den Zeitraum 1985-1987. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 1, 1-110, 1985
- 2) Peinert, R.: Saisonale und regionale Aspekte der Produktion und Sedimentation von Partikeln im Meer. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 2, 1-108, 1986
- 3) Bathmann, U.V.: Zooplanktonpopulationen dreier nordatlantischer Schelfe: Auswirkungen abiotischer und biotischer Faktoren. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 3, 1-93, 1986 (Vergriffen)
- 4) Gerlach, S.A., Thiede, J., Graf, G., Werner F.: Forschungsschiff Meteor, Reise 2 vom 19. Juni bis 16. Juli 1986; Forschungsschiff Poseidon, Reise 128 vom 7. Mai bis 8. Juni 1986. Berichte der Fahrtleiter. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 4, 1-140, 1986 (Vergriffen)
- 5) Gerlach, S.A., Theilen, F., Werner, F.: Forschungsschiff Poseidon, Reise 119 vom 16. Juli bis 1. August 1985, Forschungsschiff Poseidon, Reise 120 vom 4. August bis 20. August 1985, Forschungsschiff Valdivia, Reise 201-48A vom 17. Juli bis 31. Juli 1986, Forschungsschiff Poseidon, Reise 137 vom 3. Februar bis 20. Februar 1987. Berichte der Fahrtleiter. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 5, 1-94, 1987
- 6) Altenbach, A.V., Lutze, G.F., Weinholz, P.: Beobachtungen an Benthos-Foraminiferen (Teilprojekt A3). Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 6, 1-86, 1987 (Vergriffen)
- 7) Meißner, R., Sarnthein, M., Thiede, J., Walger, E., Werner, F.: Zur Sedimentation in Borealen Meeren: Sedimentverteilung am äußeren Kontinentalrand vor Nordnorwegen (Pilotstudie Teil B). Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 7, 1-144, 1988 (Vergriffen)
- 8) Thiede, J., Gerlach, S.A., Altenbach, A., Henrich R.: Sedimentation im Europäischen Nordmeer. Organisation und Forschungsprogramm des Sonderforschungsbereiches 313 für den Zeitraum 1988-1990. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 8, 1-211 1988 (Vergriffen)

- 9) Bohrmann, G.: Zur Sedimentation von biogenem Opal im nördlichen Nordatlantik und dem Europäischen Nordmeer (DSP/ODP- Bohrungen 408, 642, 643, 644, 646 und 647). Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 9, 1-221, 1988 (Vergriffen)
- 10) Hirschleber, H., Theilen, F., Balzer, W., von Bodungen, B., Thiede, J.: Forschungsschiff Meteor, Reise 7, vom 1. Juni bis 28. September 1988. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 10, 1-358, 1988
- 11) Bodungen, B.v., Theilen, Fr., Werner, F.: Forschungsschiff Poseidon, Reise 141-2/142 vom 17.10.-18.11.87, Forschungsschiff Poseidon, Reise 146/1 vom 25.4.-11.5.88, Forschungsschiff Poseidon, Reise 146/3 vom 29.5.-19.6.88. Berichte der Fahrtleiter. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 11, 1-66, 1988 (Vergriffen)
- 12) Uenzelmann, G.: Sedimente des südlichen Äußeren Vöring- Plateaus - Eine hochauflösende reflexionsseismische Untersuchung. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 12, 1-142, 1988 (Vergriffen)
- 13) Romero-Wetzel, M.: Struktur und Bioturbation des Makrobenthos auf dem Vöring-Plateau (Norwegische See). Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 13, 1-204, 1989
- 14) Hempel, P.: Der Einfluß von biogenem Opal auf die Bildung seismischer Reflektoren und die Verbreitung opalreicher Sedimente auf dem Vöring Plateau. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 14, 1-131, 1989
- 15) Holler, P. & Kassens, H.: Sedimentphysikalische Eigenschaften aus dem Europäischen Nordmeer (Datenreport F.S. METEOR, Reise 7). Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 15, 1-61, 1989
- 16) Philipp, J.: Bestimmung der Kompressions- und Scherwellengeschwindigkeit mariner Sedimente an Kastenlotkernen: Entwicklung einer Meßapparatur und Vergleich mit sedimentologischen Parametern. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 16, 1-95, 1989
- 17) Noji, T.: The influence of zooplankton on sedimentation in the Norwegian Sea. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 17, 1-183, 1989
- 18) Linke, P.: Lebendbeobachtungen und Untersuchungen des Energiestoffwechsels benthischer Foraminiferen aus dem Europäischen Nordmeer. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 18, 1-123, 1989

- 19) Pilnay, C., Thomsen, L. & Altenbach, A.V.: Methodische Ansätze zur Biomassebestimmung mittels biochemischer Parameter und der computergestützten Bildanalyse. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 19, 1-155, 1989 Der Artikel von Frau Pilnay erhielt den A.-Barthel-Preis 1990
- 20) Mintrop, L.J.: Aminosäuren - Analytische Methodik und Ergebnisse aus der Norwegischen See. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 20, 1-217, 1990 (Vergriffen)
- 21) Heeger, T.: Elektronenmikroskopische Untersuchungen zur Ernährungsbiologie benthischer Foraminiferen. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 21, 1-139, 1990
- 22) Baumann, K.-H.: Veränderlichkeit der Coccolithophoridenflora des Europäischen Nordmeeres im Jungquartär. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 22, 1-146, 1990 (Vergriffen)
- 23) Vogelsang, E.: Paläo-Ozeanographie des Europäischen Nordmeeres an Hand stabiler Kohlenstoff- und Sauerstoffisotope. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 23, 1-136, 1990 (Vergriffen)
- 24) Kassens, H.: Verfestigte Sedimentlagen und seismische Reflektoren: Frühdiagenese und Paläo-Ozeanographie in der Norwegischen See. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 24, 1-117, 1990 (Vergriffen)
- 25) Samtleben, C., Schröder, A.: Coccolithophoriden-Gemeinschaft und Coccolithen-Sedimentation im Europäischen Nordmeer. Zur Abbildung von Planktonzönosen im Sediment. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 25, 1-60, 1990
- 26) Antia, A., Bauerfeind, E., v. Bodungen, B., Hassan, M., Humborg, C., König, H., Koeve, W., Langmaack, H., Machado, E., Peeken, I., Petersen, H., Podewski, S., Przygodda, K., Scholten, J., Voß, M., Wunsch, M.: POSEIDON-Reise 173/2 vom 14. August bis 10. September 1990. Pelagisches System und vertikaler Partikelfluß im Herbst in der Grönländischen See, Jan Mayen Strom. Teilprojekt A1 und A 4 des Sonderforschungsbereiches 313 an der Universität Kiel. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 26, 1-54, 1990
- 27) Ritzrau, W.: Methodische Ansätze zur Bearbeitung von bodennahen Trübezonen. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 27, 1-92, 1990

- 28) Thiede, J., Gerlach, S.A., Altenbach A.V.: Veränderungen der Umwelt: Der nördliche Nordatlantik. Organisation und Forschungsprogramm des Sonderforschungsbereiches 313 für den Zeitraum 1991 - 1993. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 28, 1-249, 1990
- 29) Paetsch, H.: Sedimentation im Europäischen Nordmeer: Radioisotopische, geochemische und tonmineralogische Untersuchungen spätquartärer Ablagerungen. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 29, 1-102, 1991
- 30) Bischof, J.: Dropstones im Europäischen Nordmeer. Indikatoren für Meeresströmungen in den letzten 300 000 Jahren. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 30, 1-200, 1991
- 31) Thies, A.: Die Benthos-Foraminiferen im Europäischen Nordmeer. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 31, 1-97, 1991
- 32) Voß, M.: Räumliche und zeitliche Verteilung stabiler Isotope ($\delta^{15}\text{N}$, $\delta^{13}\text{C}$) in suspendierten und sedimentierten Partikeln im Nördlichen Nordatlantik. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 32, 1-130, 1991
- 33) Antia, A.N.: Microzooplankton in the pelagic food web of the East Greenland Sea and its role in sedimentation processes. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 33, 1-109, 1991
- 34) Birgisdottir, L.: Die paläo-ozeanographische Entwicklung der Islandsee in den letzten 550 000 Jahren. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 34, 1-186, 1991
- 35) Köster, M.: Mikrobieller Abbau von organischem Material an Grenzzonen. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 35, 1-148, 1992
- 36) Blaume, F.: Hochakkumulationsgebiete am norwegischen Kontinentalhang: Sedimentologische Abbilder Topographie- geführter Strömungsmuster. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 36, 1-150, 1992
- 37) Ziebis, W.: Experimente im Strömungskanal zum Einfluß der Makrofauna auf den bodennahen Partikeltransport. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 37, 1-83, 1992
- 38) Struck, U.: Zur Paläo-Ökologie benthischer Foraminiferen im Europäischen Nordmeer während der letzten 600.000 Jahre. Ber. Sonderforschungsbereich 313, Univ. Kiel, Nr. 38, 1-129, 1992

Henrich, R.: Sedimentologisch-fazielle Untersuchungen an glazial/interglazialen und präglazialen Ablagerungen des Europäischen Nordmeeres.

Samtleben, C. & Bickert, T.: Coccoliths in sediment traps from the Norwegian Sea.

Graf, G.: Die Reaktionen des Benthals auf den saisonalen Partikelfluß und die laterale Advektion, sowie deren Bedeutung für Sauerstoff- und Kohlenstoffbilanzen.

Verzeichnis der SFB-Publikationen (Stand Mai 1993)

- 1) Thiede, J.,
Gerlach, S.A. &
Wefer, G. *Sedimentation im Europäischen Nordmeer,
Organisation und Forschungsprogramm
des Sonderforschungsbereichs 313
für den Zeitraum 1985-1987.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 1, 1-110, 1985
- 2) Peinert, R. *Saisonale und regionale Aspekte der
Produktion und Sedimentation von
Partikeln im Meer.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 2, 1-108, 1985
- 3) Bathmann, U.V. *Zooplanktonpopulationen dreier nord-
atlantischer Schelfe: Auswirkungen
abiotischer und biotischer Faktoren.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 3, 1-93, 1986
- 4) Thiede, J.,
Diesen, G.W.,
Knudsen, B.-E. &
Snare, T. *Patterns of cenozoic sedimentation in
the Norwegian-Greenland Sea.
Mar. Geol. 69, 323-352, 1986
- 5) Peinert, R. *Production, grazing and sedimentation
in the Norwegian Coastal Current.
NATO ASI Series, G 7. The role of
freshwater outflow in coastal marine
ecosystems. Ed. by S. Skreslet.
Springer-Verlag Berlin, Heidelberg,
361-374, 1986
- 6) Smetacek, V. *Impact of freshwater discharge on
production and transfer of materials
in the marine environment.
NATO ASI Series, G 7. The role of
freshwater outflow in coastal marine
ecosystems. Ed. by S. Skreslet.
Springer-Verlag Berlin, Heidelberg,
85-106, 1986
- 7) Henrich, R. *A calcite dissolution pulse in the
Norwegian-Greenland Sea during the
last deglaciation.
Geol. Rundschau 75/3, 805-827, 1986
- 8) Noji, T.,
Passow, U. &
Smetacek, V. *Interaction between pelagial and
benthic during autumn in Kiel Bight.
I. Development and sedimentation of
phytoplankton blooms.
Ophelia 26, 333-349, 1986

- 19) Bodungen, B. v.,
Nöthig, E.-M. &
Sui, Q. *New production of phytoplankton and
sedimentation during summer 1985 in the
South Eastern Weddell Sea.
Comp. Biochem. Physiol., 90B/3,
475-487, 1988
- 20) Bodungen, B. v.,
Fischer, G.
Nöthig, E.-M. &
Wefer, G. *Sedimentation of krill faeces during
spring development of phytoplankton
in Bransfield Strait, Antarctica.
Mitt. Geol.-Paläont. Inst. Univ.
Hamburg. SCOPE/UNEP Sonderbd., 62,
243-257, 1987
- 21) Gerlach, S.-A. *Plastic and seaweeds in the offshore
Norwegian Sea.
Mar. Pollution Bull. 18/5, 246, 1987
- 22) Gerlach, S.-A.,
Thiede, J.,
Graf, G. &
Werner, F. *Forschungsschiff Meteor, Reise 2 vom
19. Juni bis 16. Juli 1986.
Forschungsschiff Poseidon, Reise 128
vom 7. Mai bis 8. Juni 1986.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 4, 1-140, 1986
- 23) Jansen, E.,
Bleil, U.,
Henrich, R.,
Kringstad, L. &
Slettemark, B. *Paleoenvironmental changes in the
Norwegian Sea and the North-East
Atlantik during the last 2.8 m.y.:
Deep Sea Drilling Project/Ocean
Drilling Program Sites 610, 642,
643 and 644.
Paleoceanography, 3/5, 563-581, 1988
- 24) Jensen, P. *Four new nematode species, abundant
in the deep-sea benthos of the
Norwegian Sea.
Sarsia 73, 149-155, 1988
- 25) Jensen, P. *Nematode assemblages in the deep-sea
benthos of the Norwegian Sea.
Deep-Sea Res. 3/7, 1173-1184, 1988
- 26) Erlenkeuser, H. &
Balzer, W. *Rapid appearance of Chernobyl radiocesium
in the deep Norwegian Sea sediments.
Oceanologica Acta 11/1, 101-106, 1988
- 27) Gerlach, S.A.,
Theilen, F. &
Werner, F. *Forschungsschiff Poseidon, Reise 119
vom 16. Juli bis 1. August 1985
Forschungsschiff Poseidon, Reise 120
vom 4. August bis 20. August 1985
Forschungsschiff Valdivia, Reise 201-48A
vom 17. Juli bis 31. Juli 1986
Forschungsschiff Poseidon, Reise 137
vom 3. Februar bis 20. Februar 1987.
Berichte der Fahrtleiter.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 5, 1-94, 1987

- 28) Henrich, R. *Glacial/interglacial cycles in the Norwegian Sea: sedimentology, paleo-oceanography, and evolution of Late Pliocene Quaternary northern hemisphere climate.
In: Eldholm, O., Thiede, J., Taylor, E. et al., Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program), 189-232, 1989
- 29) Henrich, R. *Diagenetic environments of authigenic carbonates and OPAL-CT crystallization in lower miocene to upper oligocene deposits of the Norwegian Sea (ODP Site 643, LEG 104).
In: Eldholm, O., Thiede, J., Taylor, E. et al., Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program), 233-247, 1989
- 30) Henrich, R.,
Kassens, H.,
Vogelsang, E. &
Thiede, J. *Sedimentary facies of glacial-interglacial cycles in the Norwegian Sea during the last 350 ka.
Mar. Geol., 86, 283-319, 1989
- 31) Romero-Wetzel, M.B. *Sipunculans as inhabitants of very deep, narrow burrows in deep-sea sediments.
Mar. Biol. 96, 87-91, 1987
- 32) Romero-Wetzel, M.B. *Branched burrow-systems of the enteropneust *Stereobalanus canadensis* (Spengel) in deep-sea sediments of the Vöring-Plateau, Norwegian Sea.
Sarsia 74, 85-89, 1989
- 33) Altenbach, A. &
Weinholz, P. *GEM im Labor.
ST Computer-Zeitschrift 5, 75-78, 1987
- 34) Thiede, J.,
Gerlach, S.A. &
Peinert, R. *SFB 313 "Sedimentation im europäischen Nordmeer: Abbildung und Geschichte der ozeanischen Zirkulation".
Christiana Albertina 26, 121-159, 1988
- 35) Haake, F.W. &
Pflaumann, U. *Late Pleistocene foraminiferal stratigraphy on the Vöring Plateau, Norwegian Sea.
Boreas 18, 343-356, 1989
- 36) Balzer, W. Particle mixing processes in deep Norwegian Sea sediments: evidence for seasonal effects.
- 37) Meissner, R. &
Köpnick, M. *Structure and evolution of passive margins: the plume model again.
Journ. Geodynamics 9, 1-13, 1988

- 38) Theilen, F., Uenzelmann, G. & Gimpel, P. Sediment distribution at the outer Vöring Plateau from reflection seismic investigations. Marine Geophysical Research.
- 39) Henrich, R., Wolf, T., Bohrmann, G. & Thiede, J. *Cenocoic paleoclimatic and paleoceanographic changes in the northern hemisphere revealed by variability of coarse-fraction composition in sediments from the Vöring Plateau.- LEG 104 drill sites. In: Eldholm, O., Thiede, J., Taylor, E. et al., Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program), 75-188, 1989
- 40) Kassens, H. & Sarnthein, M. *A link between paleoceanography, early diagenetic cementation, and shear strength maxima in late quaternary deep-sea sediments? Paleoceanography 4/3, 253-269, 1989
- 41) Eldholm, O., Thiede, J., Taylor, E. et al. *Proceedings, Initial Reports (Part A), of the Ocean Drilling Program. 104, 53-771, 1987
- 42) Kachholz, K.-D. & Henrich, R. *Verschiedene Experimente mit der Sedimentationswaage. Broschüre des SFB 313, 1987
- 43) Thiede, J. *The seas around Norway and their geological history. In: Varjo & Tietze (eds.) "Norden - Man and Environment. Gebr. Borntraeger, Stuttgart, 32-42, 1987
- 44) Kögler, F. *Fahrtbericht Poseidon-Fahrt 139/1 vom 3.8.-9.8.87. Broschüre des SFB 313
- 45) Altenbach, A.V., Lutze, G.F. & Weinholz, P. *Beobachtungen an Benthos-Foraminiferen (Teilprojekt A3). Ber. Sonderforschungsbereich 313, Univ. Kiel, 6, 1-86, 1987
- 46) Jansen, E., Slettemark, B., Bleil, U., Henrich, R., Kringstad, L. & Rolfsen, S. *Oxygen and carbon isotop stratigraphy and magnetostratigraphy of the last 2.8 Ma: Paleoclimatic comparisons between the Norwegian Sea and the North Atlantic. In: Eldholm, O., Thiede, J., Taylor, E. et al., Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program), 255-272, 1989



- 47) Honjo, S.,
Wefer, G.,
Manganini, S.J.,
Asper, V.L. &
Thiede, J. Seasonality of oceanic particle fluxes
in the Lofoten Basin, Nordic Sea.
submitted
- 48) Honjo, S.,
Manganini, S.J. &
Wefer, G. *Annual particle flux and a winter
outburst of sedimentation in the
northern Norwegian Sea.
Deep Sea Res., 35/8, 1223-1234,
1988
- 49) Graf, G.,
Martens, V.,
Queisser, W.,
Weinholz, P. &
Altenbach, A. *A multicalorimeter for the study of
biological activity in marine
sediments.
Mar. Ecol. Prog. Ser. 45, 201-204,
1988
- 50) Peinert, R.,
Bodungen, B. v. &
Smetacek, V. *Food web structure and loss rate.
In: W.H. Berger, V.S. Smetacek &
G. Wefer: Productivity of Ocean:
Present and Past, Report of the
Dahlem Workshop, Berlin 1988.
John Wiley & Sons, 35-48, 1989.
- 51) *Fahrtbericht Poseidon-Fahrt 144
vom 12.2. - 17.2.1988, Kattegat.
Broschüre des SFB 313
- 52) Heeger, T. *Virus-like particles and cyto-
pathological effects in Elphidium
excavatum clavatum, a benthic
foraminiferan.
Diseases of Aquatic Organisms 4,
233-236, 1988
- 53) Weinholz, P. *FOCOS, eine Methode zum Zählen von
Mikrofossilien mit Hilfe eines
Personal-Computers.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 6, 5-16, 1987
- 54) Lutze, G.F. &
Thiel, H. *Cibicidoides wuellerstorfi and
Planulina ariminensis, elevated
epibenthic Foraminifera.
s.o., 17-30
- 55) Lutze, G.F. &
Altenbach, A.V. *Rupertina stabilis (WALLICH), eine
hochangepaßte, filtrierende Benthos-
Foraminifere.
s.o., 31-46
- 56) Altenbach, A.V.,
Unsöld, G. &
Walger, E. *The hydrodynamic environment of
Saccorhiza ramosa (BRADY).
s.o., 47-68

- 57) Lutze, G.F. & Salomon, B. *Foraminiferen-Verbreitung zwischen Norwegen und Grönland: ein West-Ost Profil. s.o., 69-78
- 58) Lutze, G.F. *Benthische Foraminiferen: Vertikale Verteilung in den obersten Sedimentlagen und Probleme bei der Entnahme von Standard-Proben. s.o., 79-87
- 59) Meissner, R., Sarnthein, M., Thiede, J., Walger, E. & Werner, F. *Zur Sedimentation in borealen Meeren: Sedimentverteilungen am äußeren Kontinentalrand vor Nord-Norwegen (Pilotstudie Teil B). Ber. Sonderforschungsbereich 313, Univ. Kiel, 7, 1-144, 1988
- 60) Thiede, J., Gerlach, S.A., Altenbach, A. & Henrich, R. *Sedimentation im Europäischen Nordmeer. Organisation und Forschungsprogramm des Sonderforschungsbereiches 313 für den Zeitraum 1988-1990 Ber. Sonderforschungsbereich 313, Univ. Kiel, 8, 1-211, 1988
- 61) Bohrmann, G. *Zur Sedimentationsgeschichte von biogenem Opal im nördlichen Nordatlantik und dem Europäischen Nordmeer (DSDP/ODP-Bohrungen 408, 642, 643, 644, 646 und 647). Ber. Sonderforschungsbereich 313, Univ. Kiel, 9, 1-221, 1988
- 62) Bathmann, U.V., Noji, T.T. & Bodungen, B. v. *Copepod grazing potential in late winter in the Norwegian Sea - A factor in the control of spring phytoplankton growth? Mar. Ecol. Prog. Ser. 60, 225-233, 1990
- 63) Lampitt, R.L., Noji, T. & Bodungen, B. v. *What happens to zooplankton faecal pellets? Implications for material flux. Marine Biology 104, 15-23, 1990
- 64) Holler, P. *Sedimentäre Rutschmassen in der Tiefsee. Submarine landslides in the deep-sea. Berichte - Reports, Geol.-Paläont. Inst. Univ. Kiel, 23, 1-141, 1988
- 65) Bathmann, U.V., Peinert, R., Noji, T. & Bodungen, B. v. *Pelagic Origin and Fate of sedimenting Particles in the Norwegian Sea. Prog.Oceanog. 24, 117-125, 1990

- 66) Noji, T.T.,
Estep, K.,
MacIntyre, F. &
Norrbin, F. *Image analysis of fecal material grazed
upon by three species of copepods: Evi-
dence for coprorhexy, coprophagy and
coprochaly. J.mar.biol.Assoc. U.K. 71,
465-480, 1991
- 67) Schrader, H. &
Karpuz, N.
(Univ. Bergen) *Norwegian-Iceland seas: Transfer
Functions Between Marine Planktic
Diatoms and Surface Water Temperature.
In: Bleil, U. & Thiede, J. (eds.):
Geological History of the Polar Oceans:
Arctic versus Antarctic. NATO ASI
Series C, Kluver Acad. Publ., 337-361
- 68) Hirschleber, H.,
Theilen, F.,
Balzer, W.,
Bodungen, B. v. &
Thiede, J. *Forschungsschiff Meteor, Reise 7, vom
1. Juni bis 28. September 1988.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 10, 1-358, 1988
- 69) Bodungen, B. v.,
Theilen, Fr. &
Werner, F. *Poseidon-Reise 141-2/142 vom
17.10.-18.11.87,
Poseidon-Reise 146/1 vom 25.4.-11.5.88,
Poseidon-Reise 146/3 vom 29.5.-19.6.88.
Berichte der Fahrtleiter.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 11, 1-66, 1988
- 70) Uenzelmann, G. *Sedimente des südlichen Äußeren Vöring-
Plateaus - Eine hochauflösende
reflexionsseismische Untersuchung.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 12, 1-142, 1988
- 71) Samtleben, C. &
Bickert, T. *Coccoliths in sediment traps from the
Norwegian Sea. Marine Micropaleontology,
16, 39-64, 1990
- 72) Bohrmann, G.,
Henrich, R. &
Thiede, J. *Miocene to Quaternary Paleoceanog-
raphy in the northern North
Atlantic: Variability in carbonate
and biogenic opal accumulation.
In: Bleil, U. & Thiede, J. (eds.):
Geologic History of the Polar Oceans:
Arctic versus Antarctic. NATO ASI
Series C, Kluver Acad. Publ., 647-675
- 73) Henrich, R. *Cycles, rhythms and events in quater-
nary arctic and antarctic glaciomarine
deposits (a review). In: Bleil, U.
& Thiede, J. (eds.): Geologic History of
the Polar Oceans: Arctic versus Antarctic.
NATO ASI Series C, Kluver Acad. Publ.,
213-244

- 74) Henrich, R. *Cycles, rhythms, and events on high input and low input glaciated continental margins.
In: Einsele et al. (Eds.). (Springer-Verlag) Cycles and Events in Stratigraphy, Chapter 6, 751-772, 1991
- 75) Romero-Wetzel, M. *Struktur und Bioturbation des Makrobenthos auf dem Vöring-Plateau (Norwegische See).
Ber. Sonderforschungsbereich 313, Univ. Kiel, 13, 1-204, 1989
- 76) Hempel, P. *Der Einfluß von biogenem Opal auf die Bildung seismischer Reflektoren und die Verbreitung opalreicher Sedimente auf dem Vöring Plateau.
Ber. Sonderforschungsbereich 313, Univ. Kiel, 14, 1-131, 1989
- 77) Williams, P.J.leB., *Group Report
Bodungen, B. v., Export Productivity from the Photic
(Rapporteurs) Zone.
Bathmann, U.V., In: W.H. Berger, V.S. Smetacek &
Berger, W.H., G. Wefer (eds.): Productivity of the
Eppley, R.W., Ocean: Present and Past, Report of
Feldman, G.C., the Dahlem Workshop, Berlin 1988,
Fischer, G., John Wiley & Sons, 99-115, 1989
Legendre, L.,
Minster, J.-F.,
Reynolds, C.S.,
Smetacek, V.S. &
Toggweiler, J.R.
- 78) Bruland, K.W., *Group Report
(Rapportuer) Flux to the Seafloor.
Bienfang, P.K., In: W.H. Berger, V.S. Smetacek &
Bishop, J.K.B., G. Wefer (eds.): Productivity of the
Eglinton, G., Ocean: Present and Past, Report of
Ittekkot, V.A.W., the Dahlem Workshop, Berlin 1988
Lampitt, R., John Wiley & Sons, 193-215, 1989
Sarnthein, M.,
Thiede, J.,
Walsh, J.J. &
G. Wefer
- 79) Altenbach, A.V. & *Productivity Record in Benthic Foraminifera.
Sarnthein, M. In: W.H. Berger, V.S. Smetacek &
G. Wefer (eds.): Productivity of the
Ocean: Present and Past, Report of
the Dahlem Workshop, Berlin 1988,
John Wiley & Sons, 255-269, 1989

- 80) Jumars, P.A.,
(Rapporteur)
Altenbach, A.V.,
De Lange, G.J.,
Emerson, S.R.,
Hargrave, B.T.,
Müller, P.J.,
Prahl, F.G.,
Reimers, C.E.,
Steiger, T. &
Süß, E. *Group Report
Transformation of Seafloor-arriving
Fluxes into the Sedimentary Record.
In: W.H. Berger, V.S. Smetacek &
G. Wefer (eds.): Productivity of the
Ocean: Present and Past, Report of
the Dahlem Workshop, Berlin 1988,
John Wiley & Sons, 291-311, 1989
- 81) Holler, P. &
Kassens, H. *Sedimentphysikalische Eigenschaften aus
dem Europäischen Nordmeer (Datenreport
F.S. METEOR, Reise 7).
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 15, 1-61, 1989
- 82) Philipp, J. *Bestimmung der Kompressions- und Scher-
wellengeschwindigkeit mariner Sedimente
an Kastenlotkernen: Entwicklung einer
Meßapparatur und Vergleich mit sedi-
mentologischen Parametern.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 16, 1-95, 1989
- 83) Noji, T. *The influence of zooplankton on
sedimentation in the Norwegian Sea.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 17, 1-183, 1989
- 84) Linke, P. *Lebendbeobachtungen und Untersuchun-
gen des Energiestoffwechsels benth-
ischer Foraminiferen aus dem Euro-
päischen Nordmeer.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 18, 1-123, 1989
- 85) Meyer-Reil, L.-A. *Microorganisms in marine sediments:
considerations concerning activity
measurements.
Ergeb. Limnol. 34, 1-6, 1990
- 86) Meyer-Reil, L.-A. *Ecological Aspects of Enzymatic
Activity in Marine Sediments. In:
Microbial Enzymes in Aquatic Environ-
ments (R.J. Chrost, ed.), 84-95,
1991, Springer-Verlag, New York.
- 87) Köster, M.,
Jensen, P. &
Meyer-Reil, L.-A. *Hydrolytic Activities of Organisms
and Biogenic Structures in Deep-Sea
Sediments. In: Microbial Enzymes in
Aquatic Environments (R.J. Chrost, ed.),
298-310, 1991. Springer-Verlag,
New York.

- 88) Meyer-Reil, L.-A. & Köster, M. *Fine-scale distribution of hydrolytic activity associated with foraminiferans and bacteria in deep-sea sediments of the Norwegian-Greenland Sea. Kieler Meeresforsch., Sonderh. 8, 121-126, 1991
- 89) Altenbach, A.V. *Konstruktive Optimierung und Werkzeuggebrauch bei Einzellern. Natur und Museum 120/1, 15-18, 1990
- 90) Romero-Wetzel, M.B. & Gerlach, S.A. *Abundance, biomass, size-distribution and bioturbation potential of deep-sea macrozoobenthos on the Vøring-Plateau (1200-1500 m), Norwegian Sea. Meeresforschung 33, 247-265, 1991
- 91) Wassmann, P., Peinert, R. & Smetacek, V. *Patterns of production and sedimentation in the boreal and polar Northeast Atlantic. In: Sakshaug, E., Hopkins, C.C.E. & Sritsland, N.A. (eds.): Proceedings, Pro Mare Symposium on Polar Marine Ecology, Trondheim, 12.-16. May 1990. Polar Research 10
- 92) Linke, P. *Metabolic adaptations of deep-sea benthic foraminifera to seasonally varying food input. Mar. Ecol. Prog. Ser. 81, 51-63, 1992
- 93) Ramm, M. *Late Quaternary carbonate sedimentation and paleo-oceanography in the eastern Norwegian Sea. Boreas, 18, 255-272, 1989
- 94) Rumohr, J. A high accumulation area on the continental slope off northern Norway and sediment transport by cascading winter water. Deep Sea Res.
- 95) Eldholm, O., Thiede, J. & Taylor, E. *Evolution of the Vøring volcanic margin. In: Eldholm, O., Thiede, J., Taylor, E. et al., Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program), 1033-1067, 1989
- 96) Thiede, J., Eldholm, O. & Taylor, E. *Variability of cenozoic Norwegian-Greenland Sea, paleoceanography and northern hemisphere paleoclimate. In: Eldholm, O., Thiede, J., Taylor, E. et al., Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program), 1067-1120, 1989

- 97) Scholten, J.C., Botz, R., Mangini, A., Paetsch, H., Stoffers, P. & Vogelsang, E. *High resolution ^{230}Th stratigraphy of sediments from high latitude areas (Norwegian Sea, Fram Strait) Earth Planet. Sci. Lett., 101, 54-62, 1990
- 98) Bischof, J. *Dropstones in the Norwegian-Greenland Sea - Indications of Late Quaternary Circulation Patterns? In: Bleil, U. & Thiede, J. (eds.): Geologic History of the Polar Oceans: Arctic versus Antarctic. NATO ASI Series C, Kluwer Acad. Publ., 499-518
- 99) Graf, G. *Benthic-pelagic coupling in a deep-sea benthic community. Nature, 341/6241, 437-439, 1989
- 100) Pilnay, C., Thomsen, L. & Altenbach, A.V. *Methodische Ansätze zur Biomassebestimmung mittels biochemischer Parameter und der computergestützten Bildanalyse. Ber. Sonderforschungsbereich 313, Univ. Kiel, 19, 1-155, 1989
- 101) Mintrop, L.J. *Aminosäuren im Sediment - Analytische Methodik und Ergebnisse aus der Norwegischen See. Ber. Sonderforschungsbereich 313, Univ. Kiel, 20, 1-217, 1990
- 102) Thiede, J., Gerlach, S., Altenbach, A., Bodungen, B. v., Samtleben, C., Walger, E., Werner, F., Lutze, G., Balzer, W., Botz, R., Meißner, R., Theilen, F. & Sarnthein, M. *Sedimentation im Europäischen Nordmeer: Abbildung und Geschichte der ozeanischen Zirkulation. Bericht über den Sonderforschungsbereich 313 der Universität Kiel in den Jahren 1985 bis 1989. Mitteilung XVIII der Senatskommission für Geowissenschaftliche Gemeinschaftsforschung, 101-131, 1990
- 103) Rokoengen, K., Erlenkeuser, H., L'falldi, M. & Skarbl, O. *A climatic record for the last 12,000 years from a sediment core on the Mid-Norwegian Continental Shelf. Norsk. Geologisk Tidsskrift 71, 75-90, 1991
- 104) Andrews, J.T., Erlenkeuser, H., Evans, L.W., Briggs, W.M. & Jull, A.J.T. *Meltwater and Deglaciation, SE Baffin Shelf (NE Margin Laurentide Ice Sheet) between 13.5 and 7 KA: From O and C Stable Isotope Data, Paleoceanography 6, No. 5, 621-637, 1991

- 105) Andrews, J.T.,
Evans, L.W.,
Williams, K.M.,
Briggs, W.M.,
Jull, A.J. T.,
Erlenkeuser, H. &
Hardy, I. *Cryosphere/Ocean Interactions at the
Margin of the Laurentide Ice Sheet
during the Younger Dryas Chron: Se Baffin
Shelf, Northwest Territories.
Paleoceanography 5, 921-935, 1990
- 106) Bathmann, U.,
Noji, T. &
Bodungen, B. v. *Sedimentation of Pteropods in the
Norwegian Sea in Autumn.
Deep Sea Res. Vol. 38, Nr. 10, 1341-1360,
1991
- 107) Altenbach, A.V.,
Heeger, T.,
Linke, P.,
Spindler, M. &
Thies, A. *Millionella subrotunda* a miliolid
foraminifer building large agglutinated
tubes for a temporary epibenthic live-
style.
- 108) Botz, R.,
Erlenkeuser, H.,
Koch, J. &
Wehner, H. *Analyses of sedimentary organic matter of
a glacial/interglacial change (oxygen
isotope stage 6/5) in the Norwegian Sea.
Marine Geology 98, 113-119, 1991
- 109) Jensen, P.,
Rumohr, J.,
Graf, G. *Sedimentological and biological differen-
ces across a deep-sea ridge (Vøring
Plateau Escarpment, Norwegian Sea) expo-
sed to advection and accumulation of
fine-grained particles, Oceanologica
Acta, Vol.15-No3, 287-296, 1992
- 110) Jensen, P., *An enteropneust's nest: results of
burrowing traits by the deep-sea acorn
worm *Stereobalanus canadensis* (Spengel).
Sarsia. 77, 125-129, 1992
- 111) Jensen, P. *Nine new and less known nematode species
from the deep-sea benthos of the
Norwegian Sea. Hydrobiologia 222, 57-76,
1991
- 112) Jensen, P. **Cerianthus vogti* Danielssen, 1890.
(Anthozoa: Ceriantharia). A species
inhabiting an extended tube system
deeply buried in deep-sea sediments
off Norway. Sarsia 77, 75-80, 1992
- 113) Jensen, P. *Predatory nematodes from the deep-sea:
Description of species from the Nor-
wegian Sea, diversity of feeding types
and geographical distribution. Cahiers de
Biologie Marine 33, 1-23, 1992

- 114) Jensen, P. *Bodonematidae fam. n. (Nematoda, Chromadorida) with description of *Bodonema Vossi* gen. n. et sp. n. from the deep-sea benthos of the Norwegian Sea. *Sarsia* 76, 11-15, 1991
- 115) Köster, M., Charfreitag, O. & Meyer-Reil, L.-A. *Availability of nutrients to a deep-sea benthic microbial community: results from a ship-board experiment. *Kieler Meeresforsch.*, Sonderh. 8, 127-133, 1991
- 116) Karpuz, N.K. & Schrader, H. *Surface sediment diatom distribution and Holocene paleotemperature variations in the Greenland, Iceland and Norwegian Sea. *Paleoceanography* Vol. 5, No. 4, 557-580, 1990
- 117) Heeger, T. *Elektronenmikroskopische Untersuchungen zur Ernährungsbiologie benthischer Foraminiferen. *Ber. Sonderforschungsbereich 313, Univ. Kiel*, 21, 1-146, 1990
- 118) Weinelt, S.M., Sarnthein, M., Vogelsang, E. & Erlenkeuser, H. Early decay of Barents Shelf ice sheet - southward spread of stable isotope signals across the eastern Norwegian Sea. *Norsk Geologisk Tidsskrift*, in press
- 119) Baumann, K.-H. *Veränderlichkeit der Coccolithophoridenflora des Europäischen Nordmeeres im Jungquartär. *Ber. Sonderforschungsbereich 313, Univ. Kiel*, 22, 1-146, 1990
- 120) Vogelsang, E. *Paläo-Ozeanographie des Europäischen Nordmeeres an Hand stabiler Kohlenstoff- und Sauerstoffisotope. *Ber. Sonderforschungsbereich 313, Univ. Kiel*, 23, 1-136, 1990
- 121) Kassens, H. *Verfestigte Sedimentlagen und seismische Reflektoren: Frühdiagenese und Paläo-Ozeanographie in der Norwegischen See. *Ber. Sonderforschungsbereich 313, Univ. Kiel*, 24, 1-117, 1990
- 122) Locker, S. *30. Cenozoic Silicoflagellates, Ebridians, and Actiniscidians from the Vöring Plateau (ODP LEG 104). In: Eldholm, O., Thiede, J., Taylor, E. et al., *Proc. ODP Sci. Results, 104: College Station, TX (Ocean Drilling Program)*, 543-585, 1989
- 123) Thomsen, L. *Treatment and splitting of samples for bacteria and meiofauna biomass determinations by means of a semi-automatic image analysis system. *Mar. Ecol. Prog. Ser.* 71, 301-306, 1991

- 124) Thomsen, L. The use of Cason's modified Anilinblue stain or Bisbenzimid to differentiate between foraminifers (protozoa) and metazoa.
- 125) Altenbach, A.V. Short term processes and pattern in the foraminiferal response to organic flux rates. Mar. Micropal. (in press).
- 126) Haake, F.-W.
Erlenkeuser, H. &
Pflaumann, U. *Pullenia bulloides (ORBIGNY) in sediments of the Norwegian/Greenland Sea and the Northeastern Atlantic Ocean: Paleo-oceanographic evidence. Studies in Benthic Foraminifera, Benthos '90, Sendai 1990, p.235-244, 1992, Tokai University Press
- 127) Noji, T.T. *The influence of macrozooplankton on vertical particulate flux. Sarsia 76, 1-9, 1991
- 128) Jensen, P.,
Emrich, R. &
Weber, K. *Brominated metabolites and reduced numbers of meiofauna organisms in the burrow wall lining of the deep-sea enteropneust Stereobalanus canadensis. Deep-Sea Research 39, 1247-1253, 1992
- 129) Goldschmidt, P.M.,
Pfirman, S.L.
Wollenburg, I. &
Henrich, R. *Origin of sediment pellets from the Arctic seafloor: Sea-ice or ice berg? Deep Sea Res., 39, 539-565, 1992
- 130) Gerlach, S.A. &
Graf, G. *Europäisches Nordmeer, Reise Nr. 13, 6. Juli - 24. August 1990. Meteor-Berichte, Universität Hamburg, 91-2, 1-217, 1991.
- 131) Hempel, P.,
Lammers, S. &
Kassens, H. Methane-containing fluids in sediments of the Norwegian/Greenland Sea: Geochemical and physical property characterisation.
- 132) Paetsch, H.,
Botz, R.,
Scholten, J. &
Stoffers, P. *Accumulation rates of surface sediments in the Norwegian-Greenland Sea. Marine Geology 104, 19-30, 1992
- 133) Voss, M. *Content of copepod faecal pellets in relation to food supply in Kiel Bight and its effect on sedimentation rate. Mar.Ecol.Progr.Ser. 75, 217-225, 1991
- 134) Graf, G. &
Linke, P. *Adenosine nucleotides as indicators of deep-sea benthic metabolism. In: G.T. Rowe & V. Pariente (eds.) Deep-sea food chains and the global carbon cycle, 237-243, 1992

- 135) Kachholz, K.-D. *Haben Korngrößenverteilungen Ecken?
Schw. Naturwiss. Ver. Schlesw.-Holst.,
60, 109-117, 1990
- 136) Samtleben, C. & Schröder, A. *Coccolithophoriden-Gemeinschaften und
Coccolithen-Sedimentation im Europäi-
schen Nordmeer (Zur Abbildung von
Planktonzönosen im Sediment). Ber. Son-
derforschungsbereich 313, Univ. Kiel,
25, 1-60, 1990
- 137) Antia, A., Bauerfeind, E.,
v. Bodungen, B., Hassan, M.,
Humborg, C., König, H.,
Koeve, W., Langmaack, H.,
Machado, E., Peeken, I.,
Petersen, H., Podewski, S.,
Przygodda, K., Scholten, J.,
Voß, M. & Wunsch, M. *Poseidon-Reise 173/2 vom 14. August bis
10. September 1990.
Pelagisches System und vertikaler Par-
tikelfluß im Herbst in der Grönländi-
schen See. Jan Mayen Strom.
Ber. Sonderforschungsbereich 313,
Univ. Kiel, 26, 1-54, 1990
- 138) Gooday, A.J., Levin, L.A.,
Linke, P. & Heeger, T. *The role of benthic foraminifera in
deep-sea food-webs and carbon cycling.
In: G.T. Rowe & V. Pariente (eds.) Deep-
sea food chains and the global carbon
cycle, 63-91, 1992
- 139) Ritzrau, W. *Methodische Ansätze zur Bearbeitung von
bodennahen Trübezonen. Ber. Sonderfor-
schungsbereich 313, Univ. Kiel, 27,
1-92, 1990
- 140) Samtleben, C. & Schröder, A. *Living Coccolithophore Communities in the
Norwegian Greenland Sea and their record
in sediments. Marine Micropal. 19, 335-
354, 1992
- 141) v. Bodungen, B., Wunsch, M. &
Fürderer, H. *Sampling and analysis of suspended and
sinking Particles in the northern North
Atlantic. Geophysical Monograph 63,
47-56, 1991
- 142) Meyer-Reil, L.-A. & Charfreitag, O. *Observations on the microbial incor-
poration of thymidine and leucine in
marine sediments. Kieler Meeresforsch.,
Sonderh. 8, 117-120, 1991

- 143) Sarnthein, M.,
Jansen, E.,
Arnold, M.,
Duplessy, J.C.,
Erlenkeuser, H.,
Flatoy, A.,
Weinelt, S.M.,
Veum, T. &
Vogelsang, E. $\delta^{18}O$ Time-Slice reconstruction of melt-water anomalies at termination I in the North Atlantic between 50 and 80°N. Nato ARW Vol., in press
- 144) Thiede, J.,
Gerlach, S.A. &
Altenbach, A.V. *Veränderungen der Umwelt: Der nördliche Nordatlantik. Organisation und Forschungsprogramm des Sonderforschungsbereiches 313 für den Zeitraum 1991 - 1993. Ber. Sonderforschungsbereich 313, Univ. Kiel, 28, 1-249, 1991
- 145) Noji, T.T. *Macrozooplanktonic influence on vertical particulate flux. In Wassmann, P., Heiskanen, A.-S. & Lindahl, O. (eds.). Sediment trap studies in the Nordic countries 2. 94-115, 1991
- 146) v. Bodungen, B.,
Bathmann, U.,
Voß, M. &
Wunsch, M. *Vertical particle flux in the Norwegian Sea-Resuspension and interannual variability. In Wassmann, P., Heiskanen, A.-S. & Lindahl, O. (eds.). Sediment trap studies in the Nordic countries 2., 116-136, 1991
- 147) Antia, A.N.,
Bauerfeind, E.,
v. Bodungen, B. &
Zeller, U. *Abundance, encystment and sedimentation of acantharia during autumn 1990 in the East Greenland Sea, Journal of Plankton R., Vol. 15 no. 1, p. 99-114, 1993
- 148) Paetsch, H. *Sedimentation im Europäischen Nordmeer: Radioisotopische, geochemische und tonmineralogische Untersuchungen spät-quartärer Ablagerungen. Ber. Sonderforschungsbereich 313, Univ. Kiel, 29, 1-102, 1991
- 149) Altenbach, A. Schwammnadeln
- 150) Linke, P. &
Lutze, G.F. *Microhabitat preferences of benthic foraminifera - a static concept or a dynamic adaptation to optimize food acquisition? Marine Micropaleontology 20, 215-234, 1993
- 151) Meyer-Reil, L.-A.
& Köster, M. *Microbial life in pelagic sediments: the impact of environmental parameters on enzymatic degradation of organic material. Mar. Ecol. Prog. Ser. 81, 65-72, 1992

- 152) Bischof, J. *Dropstones im Europäischen Nordmeer - Indikatoren für Meeresströmungen in den letzten 300 000 Jahren. Ber. Sonderforschungsbereich 313, Univ. Kiel, 30, 1-200, 1991
- 153) Thomsen, L. Areal distribution of foraminiferal abundance and biomass in microhabitats around an inhabited tube of a marine Echiurid.
- 154) Antia, A.N. *Microzooplankton in the pelagic food web of the East Greenland Sea and its role in sedimentation processes. Ber. Sonderforschungsbereich 313, Univ. Kiel, 33, 1-109, 1991
- 155) Scholten, J.,
Botz, R.,
Eisenhauer, A.,
Paetsch, H.,
Stoffers, P.,
Bonani, G.,
Suter, M. &
Wölfli, W. 230Thex fluxes to the sediments in the last 300.000 years: evidence from the Norwegian Sea.
- 156) Bauerfeind, E.,
Bodungen, B.v.,
Arndt, K. &
Koeve, W. Particle flux and composition of sedimenting matter in the Greenland Sea.
- 157) Linke, P.,
Suess, E.,
Martens, V.,
Rugh, W.D.,
Ziebis, W.,
Breyman, M.v.,
Carson, B. &
Kulm, L.D. Determination of flow from subduction vent.
- 158) Thiede, J. Quarternary paleo-oceanography: the Arctic Ocean and the Norwegian Greenland Sea: 7. Danske Havforskermide. Aarhus Januar 1992, Extended abstract in press
- 159) Goldschmidt, P.M. Armored and unarmored till balls from the Greenland Sea floor.
- 160) Birgisdottir, L. *Die paläo-ozeanographische Entwicklung der Islandsee in den letzten 550 000 Jahren. Ber. Sonderforschungsbereich 313, Univ. Kiel, 34, 1-186, 1991
- 161) Thies, A. *Die Benthos-Foraminiferen im Europäischen Nordmeer. Ber. Sonderforschungsbereich 313, Univ. Kiel, 31, 1-97, 1991

- 162) Voß, M. *Räumliche und zeitliche Verteilung stabiler Isotope ($\delta^{15}\text{N}$, $\delta^{13}\text{C}$) in suspendierten und sedimentierten Partikeln im Nördlichen Nordatlantik. Ber. Sonderforschungsbereich 313, Univ. Kiel, 32, 1-130, 1991
- 163) Lackschewitz, K.S., *Der aktive mittelozeanische Rücken als Sedimentationsraum - Zusammensetzung und Oehmig, R. & Wallrabe-Adams, H.-J. Dynamik der Sedimente am Kolbeinsey-Rücken (N`Island).- Zbl.Geol.Paläont. Teil I, 11, 1727-1738 1990
- 164) Lund-Hansen, L.C. & *Comparing sieve and sedimentation balance Oehmig, R. analysis of beach, lake and eolian sediments using log-hyperbolic parameters Marine Geology, 107, 139-147, 1992
- 165) Oehmig, R. & *Hydrodynamic properties and grain size Wallrabe-Adams, H.J. characteristics of volcanoclastic deposits on the Mid-Atlantic Ridge north of Iceland (Kolbeinsey Ridge). Journal of Sedimentary Petrology 63, 140-151, 1993
- 166) Oehmig, R. Entrainment of planktonic foraminifera: Effect of particle density on the critical shear stress velocity. Sedimentology. (in press)
- 167) Hargrave, B.T., Seasonal variability in particle sedimentation under permanent ice cover in the Bodungen, v. B., Arctic ocean. Continental shelf research Stoffyn-Egli, P. & Mudie, P.J. (in press)
- 168) Thomsen, L., An instrument for sampling water from Graf, G., the benthic boundary layer. Martens, V. & Steen, E.
- 169) Kuhlemann, J. Implications of a connection between Lange, H. & clay mineral variations and coarse Paetsch, H. grained debris and Lithology in the central Norwegian-Greenland Sea. Marine Geology (subm.)
- 170) Suess, E. & *Europäisches Nordmeer Reise Nr. 17, Altenbach, A. 15. Juli-29. August 1991. Meteor-Berichte, 92-3, 1-165, 1991
- 171) Köster, M. *Mikrobieller Abbau von organischem Material an Grenzzonen. Ber. Sonderforschungsbereich 313, Univ. Kiel, 35, 1-148, 1992

- 172) Baumann, K.-H. & Matthiessen, J. *Variations in surface water mass conditions in the Norwegian Sea: Evidence from Holocene coccolith and dinoflagellate cyst assemblages. Marine Micropaleontology, 20, 129-146, 1992
- 173) Michels, K. Aseparation system for sand sized samples
- 174) Struck, M., & Nees, S. *Die stratigraphische Verbreitung von Siphotextularia rolshausemi (Phleger & Parker) in Sedimentkernen aus dem Europäischen Nordmeer. Geol. Jb. A 128, 243-249, 1991
- 175) Blaume, F. *Hochakkumulationsgebiete am norwegischen Kontinentalhang: Sedimentologische Abbilder Topographie-geführter Strömungsmuster. Ber. Sonderforschungsbereich 313, Univ. Kiel, 36, 1-150, 1992
- 176) Ziebis, W. *Experimente im Strömungskanal zum Einfluß der Makrofauna auf den bodennahen Partikeltransport. Ber. Sonderforschungsbereich 313, Univ. Kiel, 37, 1-83, 1992
- 177) Struck, U. *Zur Paläo-Ökologie benthischer Foraminiferen im Europäischen Nordmeer während der letzten 600.000 Jahre. Ber. Sonderforschungsbereich 313, Univ. Kiel, 38, 1-129, 1992

* bereits erschienen

Teilprojekt A1:

PELAGISCHE PROZESSE UND VERTIKALER PARTIKELFLUß

Kurzfassungen

Nr. 33

Microzooplankton in the pelagic food web
of the East Greenland Sea
and its role in sedimentation processes

Avan N. Antle

Nr. 33

Microzooplankton in the pelagic food web

of the East Greenland Sea

and its role in sedimentation processes

Avan N. Antia

5. Summary

Microzooplankton form an integral component of pelagic food chains in the East Greenland Sea. Using experimental techniques to determine rate processes between microzooplankton, their predators and prey, it was possible to demonstrate a close coupling of the three communities, which characterized pelagic food web dynamics during summer and autumn in the investigation area. High rates of microzooplankton herbivory did not lead to increases in their standing stocks, but served rather as a link of phytoplankton carbon to higher trophic levels. Although they constituted less than 4 % of total biomass in the euphotic zone, their high turnover rates established them as dominant members of the pelagic food web in the investigation area.

The species composition of microzooplankton in the East Greenland Sea was dominated by naked ciliates and heterotrophic dinoflagellates, with tintinnids comprising less than 10 % of total number. Although the same genera were represented in both June/July 1989 and August/September 1990, species diversity was significantly higher during the latter investigation. Copepod nauplii, present among the microzooplankton in August/September 1990, were absent in June/July 1989.

Rates of herbivory of microzooplankton were measured by the seawater dilution technique of Landry and Hassett (1982), and amounted to between 21 - 39 % and 10 - 39 % of chl *a* standing stocks on a daily basis. A modification of this technique using HPLC analysis of algal pigments in August 1990 showed processes of selective grazing among the algae. High rates of consumption of dinoflagellates and prymnesiophytes were seen.

Additionally, the rate of consumption of microprotozoans by copepods of the dominant species, *Calanus hyperboreus*, was investigated, and amounted to ca. 18 % of microprotozoan standing stocks per day in the upper 25 m of the water column.

In controlled laboratory experiments the degradation of algal pigments by microprotozoan grazers was investigated using HPLC analysis. A rapid and complete degradation of chl *a* was seen in all experiments, accompanied by the transitional accumulation of intermediate breakdown products. Degradation of algal carotenoids occurred at rates different from those for chl *a*, altering the Chl:Carotenoid ratio during the experiments. It is postulated that microprotozoans could be a major pathway for the loss of chl *a* in marine environments.

The production of faecal particles by microzooplankton was investigated in a field population using fluorescent microspheres as tracer, as well as in culture experiments in the laboratory. Among the microzooplankton assemblage metazoans such as copepod nauplii were the only producers of aggregated particles; no pellet formation was seen by protozoan grazers in either of the experiments.

An analysis of sediment trap material does not accurately reflect heterotrophic processes within the euphotic zone, as seen by the absence of dominant members of the microzooplankton community. Shipboard and laboratory experimentation are thus essential in understanding the processes which lead to retention of organic carbon or its loss to deeper water layers.

Finally, it was seen that microzooplankton play a dual role in the export of organic matter from the productive layer of the ocean. Due to their small size and negligible aggregation of ingested particles, they hinder export processes, leading rather to the retention of particles and essential nutrients in the euphotic zone. This is countered by their trophic role as a significant link in the transfer of small particles to larger metazoans, which are capable of enhancing sedimentation by the formation of large faecal aggregates. The degree of coupling between the microzooplankton, their predators and prey, is thus seen to play an important role in the relationship between productivity and export.

Abundance, encystment and sedimentation of acantharia during autumn 1990 in the East Greenland Sea

Avan N. Antia, Eduard Bauerfeind, Bodo v. Bodungen and Ute Zeller

SFB 313 der Universität Kiel, Heinrich Hecht Platz 10, Olshausenstraße 40, 2300 Kiel, FRG

Abstract. The abundance and sedimentation of acantharia and their cysts was recorded in the water column and sediment traps in the East Greenland Sea in August–September 1990. Although acantharia constituted <1% of total suspended particulate organic carbon (POC) in the water column, up to 90% (average 55%) of the POC sedimenting in 100 m was present in the form of acantharian cysts during a 9 day drift experiment. Rapid dissolution of strontium sulphate, of which their shells and spines are constructed, was evidenced by their disappearance with depth in the water column, maximum dissolution occurring between 500 and 1000 m water depth. Mass encystment and sedimentation of this single group of sarcodine protozoa can have dramatic effects on the measurement of particulate fluxes in the open ocean, and may be a recurrent phenomenon in the eastern North Atlantic.

Copepod grazing potential in late winter in the Norwegian Sea – a factor in the control of spring phytoplankton growth?

U. V. Bathmann¹, T. T. Noji², B. von Bodungen³

¹ Alfred-Wegener-Institut für Polar- und Meeresforschung, Am Handelshafen 12, D-2850 Bremerhaven, Federal Republic of Germany

² Marinebiologisk Avdeling, Marine Biology Department, Boks 2550 Sør Tromsøya, N-9001 Tromsø, Norway

³ Sonderforschungsbereich 313, Universität Kiel, Olshausenstr. 40, D-2300 Kiel, Federal Republic of Germany

ABSTRACT: During a winter cruise in the Norwegian Sea, vertical distribution of zooplankton as well as grazing and defecation by calanoid copepods from different water layers were investigated. An enriched population of natural phytoplankton ($> 4 \mu\text{g chl a l}^{-1}$) served as food in grazing and defecation experiments. Results from chl *a* measurements and cell counts of the food medium before and after incubation with copepods as well as from HPLC analyses of copepod gut contents and scanning electron microscopy of the faecal pellets collected during these experiments revealed that copepods from the upper water layer (0 to 200 m) were potential active feeders. Copepods from the water layers of their maximum abundance (below 500 m) did not feed. Results implied that grazing of copepods already present in surface waters (surface overwinterers) in late winter/early spring is a vital factor affecting the pelagic biological regime in spring.

Sedimentation of pteropods in the Norwegian Sea in autumn

ULRICH V. BATHMANN,* TOM T. NOJI† and BODO VON BODUNGEN‡

(Received 8 June 1990; in revised form 9 January 1991; accepted 15 January 1991)

Abstract—Pteropod vertical distribution on the Vøring Plateau (eastern Norwegian Sea) was recorded during a 3 week drifting experiment during August 1988. Parallel to sampling of hydrographical, chemical and biological properties of the water column, sediment traps recorded vertical pelagic flux at five depth strata. Pteropods (*Limacina retroversa*) dominated the zooplankton and reached maximum values ($>13,600$ individuals m^{-3}) in the upper 25 m of the water column; the size spectrum shifted from small (<1 mm) towards large (>3 mm) specimens during the study.

Vertical flux at 100 m depth increased from 600 mg dry weight $m^{-2} day^{-1}$ to 1000 mg dry weight $m^{-2} day^{-1}$ at the end of the experiment. Trap material during the first sampling intervals consisted primarily of phytoplankton and protozoans aggregated within pteropod feeding nets. Thereafter, the increase in flux rates was associated with empty shells of pteropods in the size class 1–3 mm indicating mortality prior to mass sinking. Particle flux during the investigation period totalled 0.2 g organic C m^{-2} and 1.4 g carbonate m^{-2} equivalent to 8 and 15% of annual flux recorded in the area in 1988. Through their feeding, reproduction and subsequent mortality pteropods were the main contributors to vertical particle flux in the eastern Norwegian Sea during 1988.

Pelagic origin and fate of sedimenting particles in the Norwegian Sea

ULRICH V. BATHMANN¹, ROLF PEINERT², THOMAS T. NOH² and BODO V. BODUNGEN²

¹Alfred-Wegener-Institut für Polar- und Meeresforschung, Am Handelshafen 12, D-2850, Bremerhaven, FRG

²Sonderforschungsbereich 313, Olshausenstr. 40, D-2300 Kiel 1, FRG

Abstract—A 17 month record of vertical particle flux of dry weight, carbonate and organic carbon were 25.8, 9.4 and 2.4 g.m⁻².y⁻¹, respectively. Parallel to trap deployments, pelagic system structure was recorded with high vertical and temporal resolution.

Within a distinct seasonal cycle of vertical particle flux, zooplankton faecal pellets of various sizes, shapes and contents were collected by the traps in different proportions and quantities throughout the year (range: 0–4,500 10³m⁻²d⁻¹). The remains of different groups of organisms showed distinct seasonal variations in abundance. In early summer there was a small maximum in the diatom flux and this was followed by pulses of tintinnids, radiolarians, foraminiferans and pteropods between July and November.

Food web interactions in the water column were important in controlling the quality and quantity of sinking materials. For example, changes in the population structure of dominant herbivores, the break-down of regenerating summer populations of microflagellates and protozooplankton and the collapse of a pteropod dominated community, each resulted in marked sedimentation pulses.

These data from the Norwegian Sea indicate those mechanisms which either accelerate or counteract loss of material via sedimentation. These involve variations in the structure of the pelagic system and they operate on long (e.g. annual plankton succession) and short (e.g. the end of new production, sporadic grazing of swarm feeders) time scales. Connecting investigation of the water column with a high resolution in time in parallel with drifting sediment trap deployments and shipboard experiments with the dominant zooplankters is a promising approach for giving a better understanding of both the origin and the fate of material sinking to the sea floor.

Particle flux and composition of sedimenting matter in the Greenland Sea

E. Bauerfeind, B. v. Bodungen, K. Arndt & W. Koeve.

SFB 313, Christian Albrechts Universität, Kiel,
Heinrich Hecht Platz 10, D 2300 Kiel. Germany

Abstract

Sedimentation of particulate matter to deeper layers was recorded by means of moored sediment traps in the partially ice covered region of the Greenland Sea at 72° N during 1988/1989. Annual sedimentation to 500m amounted to 22.79, 8.55, 2.39, 3.81 and 0.51 gm⁻² of dry weight, carbonate, particulate silicate, particulate carbon and particulate nitrogen, respectively. The seasonal pattern of sedimentation revealed an increase in sedimentation in April, a peak in May-June and constantly high sedimentation rates during summer (100 mg m⁻²d⁻¹). Several *Thalassiosira* species were the dominant diatoms during the high sedimentation period. High of small pennate algae, which dominated the species composition in April, were also present. The increasing flux of biogenic particles in April is indicative of a start of enhanced algal growth in early spring. During May-June, up to 22% of the *Thalassiosira* cells observed in the traps were viable looking cells. From this and the shifted pattern of faecal pellet flux which peaked after the high sedimentation period, we conclude that sedimentation of diatoms was mainly due to the formation of aggregates. From the flux of particulate silicate a potential diatom production of 6.4 g C m⁻² during the spring period was estimated, which amounts to 25 % of new production in the same period. From this we conclude that a considerable part of phytoplankton production in the Greenland Sea during spring is due to non-diatomaceous organisms and may not be manifested in the samples of the sediment traps.

eingereicht zum Druck: J. Mar. Syst.

Sediment traps in marine ecological research and
monitoring

**VERTICAL PARTICLE FLUX IN THE NORWEGIAN SEA -
RESUSPENSION AND INTERANNUAL VARIABILITY**

Bodo v. Bodungen, Ulrich Bathmann, Maren Voß & Marita
Wunsch

Sonderforschungsbereich 313

University of Kiel

Heinrich Hecht Platz 10

D-2300 KIEL 1, F.R.G.

INTRODUCTION

Considerable seasonal and regional variations in vertical particle flux have been established in the Nordic Seas by recent sediment trap deployments in annual moorings (Honjo *et al.* 1988; Bathmann *et al.* 1991; Hebbeln & Wefer 1991). Seasonal maxima in particle flux of organic carbon are generally closely related to annual recurring phytoplankton blooms within the physico-chemical growth conditions, i.e. stabilisation of the upper water column due to ice-melt and/or the establishment of a seasonal thermocline during spring/early summer and the consequent depletion of winter accumulated nutrients and export of phytodetritus (Peinert *et al.* 1989).

In the Greenland Sea annual flux rates (dry weight) between 2.9, 60.5 and 149.9 g m⁻² were found at sites in the East Greenland Current, Central Fram Strait and West Spitsbergen Current respectively (Hebbeln & Wefer 1991). The extent of ice-cover and onset of ice-melt were predominant in determining amount and seasonality of flux events.

SAMPLING AND ANALYSIS OF SUSPENDED AND SINKING PARTICLES IN THE NORTHERN NORTH ATLANTIC

Bodo v. Bodungen, Marita Wunsch and Heike Fürderer

Sonderforschungsbereich 313, Kiel University, Heinrich-Hecht-Platz 10, D2300 Kiel 1, FRG

1. Introduction

Comparative studies of pelagic system structure and related particle flux have been conducted in the Norwegian Basin and in the Greenland Sea since 1986/1987. These studies are part of a so-called SONDERFORSCHUNGSBEREICH 313 (Special Research Project), which is entitled: Changes In The Environment: The Northern North Atlantic. The program also encompasses investigations of the benthal, near-bottom transport, sediment accumulation, and biogeochemistry of the sediments as well as geophysical, paleoecological and oceanographic studies and modelling efforts. The overall goal of this program is to establish fluxes of biogenic elements and the related sedimentary record in the contemporary northern North Atlantic and to interpret glacial/interglacial variations in circulation, ventilation and sedimentation in this area.

Within the framework of this program, vertical export of particulate biogenic matter is recorded continuously at two time-series stations (70° N 00° W; and 73° N 07° W) with sediment traps, which are moored in three depth horizons with weekly to monthly sampling intervals. In different seasons, selected according to recurring patterns in quantity and quality of vertical flux, process-oriented studies are carried out with high spatial and temporal resolution [Peinert et al., 1987; Bathmann et al., 1990].

In this program, sampling and analysis of bioelements are done in accordance with widely used standard procedures. The investigations in the Greenland Sea are part of the JGOFS program; thus, core measurement protocols given for the NORTH ATLANTIC SPRING BLOOM STUDY are followed in general [JGOFS Report No. 6, 1990]. However, sample handling and methods are slightly altered with regard to requirements of sampling sites and particular problems addressed. Prior to such adaptations improvements versus caveats are evaluated carefully.

2. Water Column Sampling and Sample Handling

Preferably Niskin bottles mounted on a rosette sampler combined with CTD and fluorescence probes are used. When two or more water bottles are required for a discrete depth horizon, the individual water bottles are closed with as little delay as possible on the same cast. Continuous in situ recording of fluorescence has shown that internal waves can alter the vertical distribution of chlorophyll *a*-containing particles on time scales of minutes to days (R. Peinert and S. Podewski, Institut Meereskunde, Kiel, FRG, unpublished data, Figure 3-3, 1990). Sampling of the surface layer, therefore, is carried out as rapidly as possible to avoid biases in the vertical profile due to temporal inhomogeneities. At times and locations where strong internal wave action is expected, sampling at density horizons may be more appropriate than sampling from standard depths.

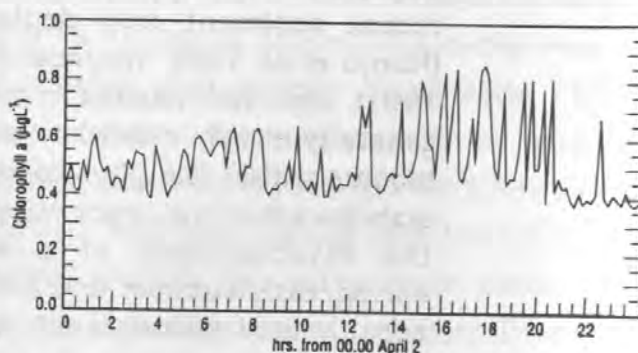
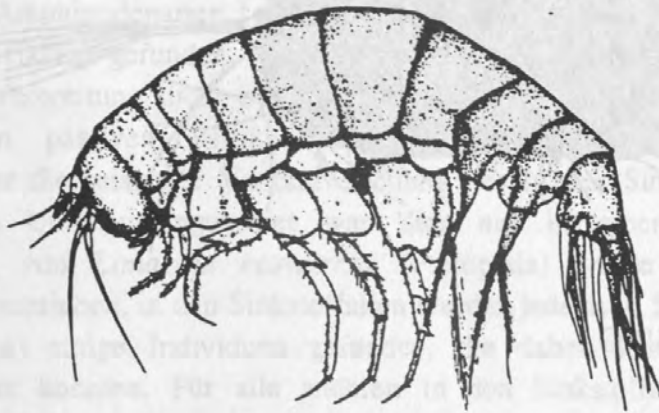


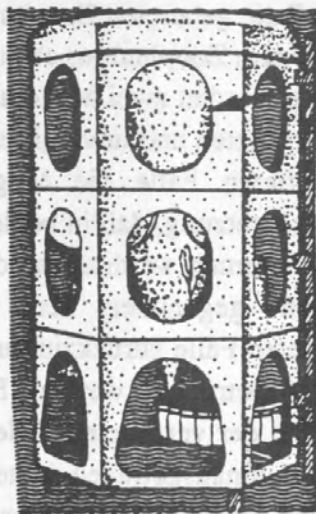
Fig. 3-3. Changes in chlorophyll *a* (CHLA) over the course of one day in 60 m water depth measured with a self-contained in situ fluorimeter. The recordings were taken at 18° N; 20° W on April 2, 1989 during METEOR-Cruise M10/1 and data were recorded in 10 min intervals (Courtesy of Peinert and Podewski). The time of day is given on the horizontal axis.

After recovery of the water bottles, the entire contents are drained into a large carboy. Immediately thereafter the respective subsamples for the various measurements are taken. Agitation of the carboy to guarantee an even distribution of particles is gentle to avoid de novo formation of particles from dissolved and colloidal material. In general samples are not prescreened as sieves may retain long diatom chains and

Aus dem Zoologischen Institut
der Christian-Albrechts-Universität zu Kiel



ZÖOPLANKTON IN SINKSTOFFFALLEN IN BEZIEHUNG ZUR VERTIKALVERTEILUNG IM EUROPÄISCHEN NORDMEER



Diplomarbeit

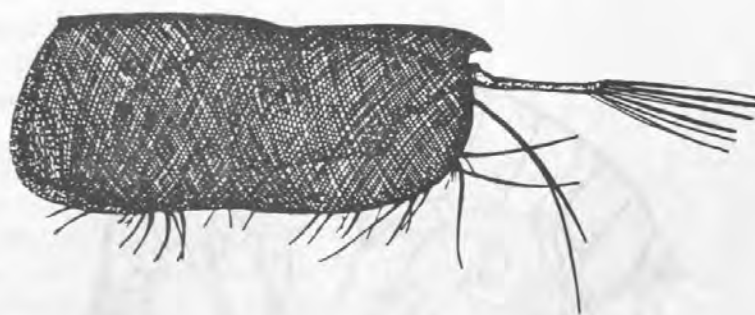
vorgelegt von

HEIKE ANTJE FÜRDERER

Kiel

September 1991

CONCHOECIA BOREALIS



6. ZUSAMMENFASSUNG

Im Rahmen der Untersuchungen des Sonderforschungsbereiches 313 wurden in Jahres- und Kurzeiteinsätzen zur Aufnahme des passiven Flusses von Partikeln durch die Wassersäule zeitgeschaltete Sinkstofffallen im Europäischen Nordmeer eingesetzt.

Durch Schwimmer (aktiv in die Fallen gelangtes Zooplankton), die einen aktiven Fluß in die Fallengläser repräsentieren, entstehen bei der Auswertung der Proben vielfältige Probleme.

In dieser Arbeit wurden Sinkstoffallenproben aus einer Kurzzeitverankerung, eines Driftexperimentes und Sinkstoffallen aus Jahresverankerungen verschiedener Tiefen und Seegebiete auf Häufigkeit und Artenzusammensetzung der Schwimmer untersucht. Ziel war es dabei, den Anteil des aktiv in die Falle gelangten Zooplanktons (Schwimmer) von dem des toten, also passiv in die Falle gesunkenen, Zooplanktons abzuschätzen.

In einem zehntägigen Driftexperiment wurden zwei Monofallen in 100m Tiefe nebeneinander eingesetzt, deren Fallengläser mit vergifteten und unvergifteten Lösungen versetzt waren. Das Zooplankton hatte in der unvergifteten Falle die Möglichkeit, wieder aus der Falle hinauszuschwimmen. Unter der Voraussetzung, daß in beiden Fallen des Drifters gleich viele Organismen schwimmen, kann angenommen werden, daß die um 93% geringere Anzahl der Schwimmer in der unvergifteten gegenüber der vergifteten Falle auf aktives Herausschwimmen aus der unvergifteten Falle zurückzuführen ist. Dieser Anteil muß dann in der vergifteten Falle als Schwimmer betrachtet werden. Ein Vergleich der Chlorophyll-a-Äquivalente aus der unvergifteten und der vergifteten Falle ergab, daß die Schwimmer kein Material aus der unvergifteten Falle hinausgetragen hatten. Parallel zum Driftexperiment genommene Multinetzproben ließen eine Affinität von *Calanus hyperboreus* zu den Sinkstoffallen erkennen. *Calanus hyperboreus* wurde in den Sinkstoffallenproben in größeren Prozentanteilen an der Gesamtanzahl der Schwimmer gefunden als in den Prozentanteilen an der Zooplanktonabundanz aus der Wassersäule.

Im Vergleich der Kurzzeitverankerung mit dem parallel eingesetzten Drifter wurden in den Sinkstoffallenproben der Kurzzeitverankerung 76% weniger Schwimmer gefunden. Dieses könnte durch erhöhte Turbulenzen an den festverankerten Sinkstoffallen und entsprechender erhöhter Meidung der Fallen durch das Zooplankton gegenüber der driftenden Falle hervorgerufen werden. Zusätzlich können mesoskalige Unterschiede in Menge und Zusammensetzung der Zooplanktonpopulation für diese Befunde von Einfluß sein.

Für den Jahreseinsatz wurden die Informationen aus der Literatur über die saisonale Vertikalverteilung der einzelnen Zooplanktonarten mit den Ergebnissen aus den Sinkstoffallenproben der Jahresverankerungen verglichen. Dabei wurden bestimmte Copepoden- und Amphipodenarten bezüglich der in unterschiedlichen Tiefen eingesetzten Sinkstoffallen ganzjährig gefunden. Wurde in einer Sinkstoffalle Zooplankton gefunden, dessen vertikale Verbreitung nicht bis in die Einsatztiefe der Falle reicht, konnte dieses Zooplankton dem passiven Partikelfluß zugeordnet werden. Durch ungenügende Informationen über die saisonale Vertikalverteilung des in den Sinkstoffallen gefundenen Zooplanktons im Untersuchungsgebiet war dies nur in einem Fall möglich. Die Vertikalverteilung von *Limacina retroversa* (Pteropoda) wurde in der Literatur als oberflächennah beschrieben, in den Sinkstoffallen wurden jedoch in 500m (Norwegische und Grönländische See) einige Individuen gefunden, die daher dem passiven Partikelfluß zugeordnet werden konnten. Für alle anderen in den Sinkstoffallenproben gefundenen Zooplanktonarten konnte aufgrund von Informationen aus anderen Seegebieten nicht ausgeschlossen werden, daß diese lebend in die Falle gelangt sind.

Der Vergleich der Schwimmer aus Sinkstoffallen, die jeweils ein Jahr in der Norwegischen und der Grönländischen See verankert waren, ergab eine um die Hälfte geringere Anzahl der Schwimmer in den Sinkstoffallenproben der Norwegischen See. Weiterhin ergab die Auswertung von einigen Gläsern einer Verankerung eines vorhergehenden Jahres in der Grönländischen See, daß die Anzahl der Schwimmer in Sinkstoffallenproben von Jahr zu Jahr stark variieren kann.

Seasonal variability in particle sedimentation under permanent ice cover in the Arctic Ocean

B. T. HARGRAVE,* B. VON BODUNGEN,† P. STOFFYN-EGLI‡ and P. J. MUDIES§

(Received 26 February 1992; accepted 16 June 1992)

Abstract—A study at 79°N over the polar continental shelf off Ellef Ringes Island in 1989–1990 provided year-round measurements of particulate matter sedimentation in a permanently ice covered region of the Arctic Ocean. Mean annual flux rates of mass (1.1 g m^{-2}), organic carbon (134 mg m^{-2}), nitrogen (24 mg m^{-2}), chlorophyll *a* (3 mg m^{-2}) and biogenic silicon (11 mg m^{-2}) were determined by deployment of two sediment traps from the Canadian Ice Island at a water depth of 100 m. High fluxes of mass, biogenic silicon and inorganic matter occurred between July and September during the melt-water runoff. Maximum sedimentation of organic matter and chlorophyll *a* occurred in August and September when centric diatoms and zooplankton fecal pellets were numerous in samples. Between February and June, when mass fluxes were low, settled particles were organically rich with low carbon:nitrogen ratios (4–8) in contrast to higher values (6–12) during the melt-water period. Mineralogy showed that chlorite, mica, illite and quartz were abundant in settled particles collected in August, October and December. Similar minerals, thought to be supplied as small particles by eolian transport, are present in ice cores and cryoconites on the Ice Island. The observations provide data for assessing future changes in production and particle export for this ice-covered region of the Arctic Ocean that may be altered due to global warming and related changes in ice cover.

Aus dem Institut für Meereskunde
an der Christian - Albrechts - Universität
zu Kiel

**Die Exsudation des Phytoplanktons
in der westlichen Grönlandsee**

Diplomarbeit

vorgelegt von

Moshira Hassan

Kiel, Juni 1991

V. ZUSAMMENFASSUNG

In zwei Tankexperimenten (Volumen der Tanks jeweils 1 m^3) im Labor in Kiel sollte die DOC-Exsudation durch Phytoplankton während einer Phase überwiegend neuer Produktion sowie die kurzfristige Aufnahme der Exsudate durch Bakterien mit Hilfe der ^{14}C -Methode untersucht werden.

In Tank 3 (*S. costatum* Kultur) bestand eine lineare Abhängigkeit zwischen Exsudation und CO_2 -Fixierung. Der Anteil der Exsudation an der Gesamt- CO_2 -Fixierung (PER = percent extracellular release) lag während der exponentiellen Wachstumsphase des Phytoplanktons zwischen 20% und 26%. Die bakterielle Inkorporation von Exsudaten zeigte eine deutliche Abhängigkeit von der Exsudation. Insgesamt wurden in Tank 3 zwischen 2% und 21% des photosynthetisch fixierten Kohlenstoffes in Bakterienbiomasse eingebunden.

In Tank 4 (Mischkultur aus der Grönlandsee) konnten ähnliche Abhängigkeiten für die ersten vier Versuchstage gefunden werden. Die PER lag in diesem Tank zwischen 6% und 33%. Es wurden zwischen 1% und 9% des gesamtfixierten Kohlenstoffes in Bakterienbiomasse überführt.

In sechs Kulturexperimenten wurde die Bildung von PDOC (photosynthetisch produzierter gelöster organischer Kohlenstoff) in 5l Glasflaschen mit Hilfe der ^{14}C -Methode untersucht.

Kulturflasche P1 wurde an Bord des FS 'POSEIDON' mit Wasser aus Tank 1 angesetzt, der in der Grönlandsee ($72^{\circ}40,04\text{N}$; $07^{\circ}35,49\text{W}$) mit Oberflächenwasser (5m) gefüllt wurde. Die Partikelproduktion und die Bildung von PDOC zeigten einen deutlichen Tagesrhythmus. Tagsüber wurde eine geringe Produktion von PPOC (photosynthetisch produzierter partikulärer organischer Kohlenstoff) verzeichnet. Bei Nacht nahm die PPOC Konzentration ab und die PDOC-Konzentration zu. Ein Vergleich mit den in-situ Verhältnissen und den Verhältnissen in Tank 1

ergab, daß die geringe CO₂-Fixierung bei Tag vermutlich auf den schlechten physiologischen Zustand der Phytoplanktonzellen zurückzuführen ist, die z.T. in eine winterliche Ruhephase eingetreten waren. Die PDOC-Bildung bei Nacht lag vermutlich an einer verstärkten Lysis seneszenten Zellen bei Nacht.

Die Kulturexperimente im Labor in Kiel wurden mit je zwei Kulturen aus Tank 3 und Tank 4 durchgeführt. In allen Kulturen wurde ein starker Biomasseaufbau verzeichnet. Die PDOC-Akkumulation betrug in allen Kulturen zwischen 9% und 14% des gesamtfixierten Kohlenstoffes.

Die Aufnahme des in den Kulturen K1 und K4 akkumulierten ¹⁴C-PDOC durch eine Bakterienreinkultur wurde sieben Mal im Verlaufe des Kulturexperimentes untersucht. Es konnte eine Zunahme der bakteriellen Inkorporation von PDOC bei steigender PDOC-Ausgangskonzentration festgestellt werden.

Die prozentuale Aufnahme von PDOC innerhalb einer 24-stündigen Inkubation nahm hingegen im Verlaufe der Zeit ab. Da die PDOC-Aufnahme-Experimente unter konstanten Bedingungen durchgeführt wurden und die bakterielle Aufnahme von PDOC auf bakterielle Aktivität standardisiert wurde, lag die abnehmende prozentuale Aufnahme von PDOC vermutlich an einer Verschiebung der Qualität des PDOC zu refraktärerem Material.

ergab, daß die geringe CO₂-Fixierung bei Tag-Vermehrungskulturen

Aus dem Institut für Meereskunde
an der Christian - Albrechts - Universität
zu Kiel

Die Kulturparameter im Labor in Kiel werden mit Hilfe von

Kulturen aus Tank 3 und Tank 4 durchgeführt. In allen Kulturen

wurde ein starker Biomassezuwachs festgestellt. Die POC-Akturnahme

lieferte einen Wert zwischen 80 und 100 µg/l.

Die POC-Akturnahme wurde mit Hilfe von

Die Aufnahme von POC durch Bakterienkulturen wurde mit Hilfe von

POC durch ein Bakterienkulturen wurde mit Hilfe von

zum Umsatz von Phosphor und Stickstoff

Die POC-Akturnahme wurde mit Hilfe von

in natürlichen Planktongemeinschaften

Die prozentuale Aufnahme von POC innerhalb einer 14-tägigen

Inkubation nahm hingegen im Verlaufe der Zeit ab. Die POC

Aufnahme-Experimente unter konstanten Bedingungen durchgeführt

wurden und die POC-Akturnahme wurde mit Hilfe von

Aktivität standardisiert wurde. Die prozentuale

Aufnahme von POC vermehrt an einer Verschiebung der Quoti-

ent des POC zu reduzierendem Material.

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Die POC-Akturnahme wurde mit Hilfe von

Kiel, Mai 1991

VI. ZUSAMMENFASSUNG

Zwei Tanks (Volumen jeweils 1 m^3) wurden in der Grönlandsee (72° 40', 04' N, 07° 35', 49' W) mit Oberflächenwasser (5 m) sowie mit Wasser unterhalb der Nutrikline (70 m) gefüllt. Es sollte durch die Bilanzierung der N- und P-Komponenten gezeigt werden, wie hoch der Anteil der gelösten organischen Substanz an der Primärproduktion in einem regenerierten sowie einem System, vorwiegend basierend auf der neuen Produktion, ist. In beiden Tanks konnte nur eine geringe Biomasseakkumulation gemessen werden. Aus dem Vergleich mit Messungen aus der Wassersäule ergab sich, daß die Phytoplankter lichtlimitiert waren. Zwei weitere Tankexperimente wurden im Labor durchgeführt. In beiden Tanks wurde die Nährsalzkonzentration stark erhöht sowie konstante Lichtbedingungen geschaffen, um hohe Wachstumsraten zu garantieren. Der Anteil des gelösten organischen N an der Primärproduktion lag in beiden Tanks bei ca. 10 %. Der Anteil des gelösten organischen P bei ca. 25 %.

In drei Abbauxperimenten, die in 10 - l fassenden abgedunkelten Inkubationsgefäßen durchgeführt wurden, sollte gezeigt werden, in welchem Maße das partikuläre sowie gelöste Material einem Abbau unterliegt. Dazu wurde in Abbauxperiment I und II der Abbau der partikulären und der gelösten Komponente, in Abbauxperiment III nur der Abbau der gelösten organischen Komponente untersucht. Als Inokkulum wurden nitrifizierende Bakterien, die aus der Grönlandsee (aus 80 m Tiefe, dem sogenannten Nitritmaximum) stammten, hinzugegeben. Es konnte der Abbau bis hin zum PO_4 und NO_3 verfolgt werden, wobei P schnellere Remineralisierungsraten aufwies als N. Des weiteren konnte gezeigt werden, daß der Abbau der gelösten organischen Komponente ein sehr viel schnellerer und effektiverer Prozeß ist als der Partikelabbau. Auf der anderen Seite konnte auch eine refraktäre Komponente des gelösten organischen Materials beobachtet werden.

In der Grönlandsee wurden die Konzentrationen von Urea sowie des gelösten organischen P in der Wassersäule ermittelt. Urea konnte nur bis in Tiefen von 500 m und im bodennahen Wasserkörper nachgewiesen werden. Die Konzentrationen lagen zwischen 0.05 und 0.3 μM . Urea spielte in diesem Untersuchungszeitraum eine geringe Rolle im gelösten organischen N - Pool. Die gelöste organische P - Komponente konnte in der gesamten Wassersäule bis in ca. 3000 m Wassertiefe nachgewiesen werden. Die Konzentrationen lagen zwischen 0.1 und 0.4 μM . Da das DOP im Tiefenwasser mindestens ein Alter von einem halben Jahr haben mußte, handelt es sich hier um refraktären gelösten organischen P, der auch in den Abauversuchen festgestellt werden konnte.

In drei Abbaupartimenten, die in I - I zusammengefaßt werden, wurden Inkubationsversuche durchgeführt, um die Geschwindigkeit des Abbaus des gelösten organischen P zu untersuchen. Die Ergebnisse sind in Tabelle 1 dargestellt. Der Abbau des gelösten organischen P war in allen Partimenten sehr langsam und wurde durch die Zugabe von Urea nicht beschleunigt. Die Ergebnisse zeigen, dass der Abbau des gelösten organischen P in der Grönlandsee sehr langsam ist und dass Urea eine wichtige Rolle im Stickstoffkreislauf spielt.

Aus dem Institut für Meereskunde
an der Christian-Albrechts-Universität

New Production of Phytoplankton in the tropical and subarctic North Atlantic

Dissertation
zur Erlangung des Doktorgrades
der Mathematisch-Naturwissenschaftlichen Fakultät
der Christian-Albrechts-Universität
zu Kiel

vorgelegt von
Wolfgang Koeve

Kiel 1992

6. Summary

Measurements of new production presented in this thesis were conducted during three drift experiment in the tropical and subarctic North Atlantic.

At the **tropical study site at 18°N, 30°W** rate measurements of nitrate utilization were carried out with the nitrate disappearance technique. Rates of nitrate use peaked at the nitracline and integrated nitrate use in the euphotic zone showed a positive correlation with integrated nitrate concentrations. Both integrated nitrate use and the depth weighted mean *f*-ratio were related to the depth of the nitracline. Highest integrated nitrate use (4 to $5 \text{ mmol m}^{-2} (12\text{h})^{-1}$) and *f*-ratio (0.73 to 0.94) were observed on stations with a shallow nitracline (44 m to 60 m). Rates of nitrate use between 0 and $2 \text{ mmol m}^{-2} (12\text{h})^{-1}$ were observed at stations with a nitracline depth below 75 m .

The high variability in the vertical patterns of nitracline depth, chl *a* concentrations and nitrate use was strongly related to the frequent occurrence of the subtropical subsurface salinity maximum (S_{max}). During the drift study three groups of stations could be separated with respect to the vertical salinity, temperature, oxygen and nitrate distribution. The most interesting, and previously undescribed, feature was a subsurface nitrate maximum within the euphotic zone, which was observed at several stations.

Mechanisms of nitrate supply to the euphotic zone in tropical oceans are discussed in this thesis. While deep winter mixing is of less importance in permanently stratified systems, turbulent mixing and short term wind induced mixing events are usually proposed as the only mechanisms for nitrate supply in tropical seas. Salt fingering and double diffusion, induced by the intrusion of warm and more saline S_{max} over cold and less saline water layers, are proposed as an important additional supply mechanism at the study site.

Two field experiments were conducted in the **subpolar Jan Mayen Current** (northern North Atlantic). During both studies nitrate uptake was measured with the ^{15}N - NO_3 -uptake technique.

One drift experiment was conducted in **late spring 1989** in the vicinity of the pack ice edge. The vertical structure of the euphotic zone (1% light depth of $25 (\pm 4) \text{ m}$) was characterized by shallow mixed layer depths (10 to 18 m) with low nutrient concentrations which, however, were not limiting to phytoplankton growth, and chl *a* concentrations of 1 to $2 \mu\text{g chl } a$.

Two groups of stations could be separated with respect to vertical structure and absolute rates of nitrate uptake. During a phase with high integrated nitrate uptake rates ($3.1 (\pm 1.5) \text{ mmol N m}^{-2} \text{ d}^{-1}$) distinct maxima of NO_3 uptake were observed at the surface and nitrate uptake rates decreased rapidly with depth. During a phase with low integrated nitrate uptake rates ($0.42 (\pm 0.12) \text{ mmol N m}^{-2} \text{ d}^{-1}$) low and constant rates of nitrate uptake were observed throughout the whole euphotic zone. Patterns of primary production and of the *f*-ratio did not follow exactly the patterns of new production, but mean integrated primary production rates of $605 (\pm 93) \text{ mg C m}^{-2} \text{ d}^{-1}$ and $343 (\pm 133) \text{ mg C m}^{-2} \text{ d}^{-1}$ and mean *f*-ratios (0.4 to 0.7 and below 0.2 , respectively) resembled overall patterns of new production during phases of high and low new production.

Possible mechanisms that controlled nitrate uptake rates during late spring are discussed. Substrate availability (cNO_3), but also substrate inhibition due to NH_4 , and grazing of metazooplankton appeared to be less important in the area. Contrary to other studies from the subarctic, *N*-specific nitrate uptake decreased significantly with depth at several stations. On some of these stations the decrease with

depth appeared to be due to decreasing light availability. A general relation between nitrate uptake and radiation, however, was not evident, perhaps due to the lack of good light data.

A second drift experiment in the Jan Mayen current was conducted during autumn 1990. The vertical structure of the euphotic zone was characterized by a very shallow (10 m) nutrient depleted surface layer. Chl *a* concentrations varied between 0.5 and 1 $\mu\text{g dm}^{-3}$ and no distinct and recurring vertical structure was observed. Patterns of new and total primary production were much more homogeneous as compared to the spring experiment. Rates of integrated total primary production varied between 100 and 200 $\text{mg C m}^{-2} \text{d}^{-1}$ while integrated nitrate uptake rates between 0.12 and 0.46 $\text{mmol N m}^{-2} \text{d}^{-1}$ were observed. Depth weighted mean *f*-ratios varied between 0.1 and 0.2.

The vertical structure of absolute and N-specific nitrate uptake and the *f*-ratio showed distinct maxima just below the nitrate depleted layer. *F*-ratios as high as 0.6, and absolute and specific uptake rates 3 to 4 times as high as in the surface layer were observed in this maximum. New production rates below the maximum, however, decreased rapidly with depth.

Field data and additional nitrate uptake experiments are analysed to identify the controlling mechanisms of nitrate uptake during autumn. Substrate availability limited N-specific nitrate uptake rates in the nitrate poor surface layer. The observed decrease of N-specific nitrate uptake rates below the uptake maximum could have been either due to increasing NH_4 concentrations or decreasing light availability with depth. Experiments with samples from different depths below the *in situ* uptake maximum revealed significant light limitation of nitrate uptake. Light saturated N-specific uptake rates were 3 to 4 times as high as *in situ* rates of samples originating from the same water depth. In samples incubated at surface irradiance levels, a decrease in N-specific nitrate uptake with the depth of sample origin was seen. This is discussed in relation to *in situ* light adaptation and photoinhibition effects on samples from increasing depth below the mixed layer. Based on further evidence from analyses of the field data (scatter plots of *in situ* N-specific nitrate uptake rates vs. irradiance and cNH_4 , respectively) I conclude that light availability, light adaptation and susceptibility to photoinhibition explain the observed patterns of N-specific nitrate uptake *in situ* and in incubation at 100 % light levels, below the *in situ* maximum of nitrate uptake. NH_4 -concentrations, and hence changes in NH_4 -preference with depth, appeared to be less important in controlling nitrate uptake during the autumn drift experiment.

Seasonal and annual rates of new and export production in the Nordic Seas are estimated from seasonal nutrient and PON profiles. Two study sites are compared. The Jan Mayen Current (JMC) is depicted as an area characterized by seasonal ice cover and low importance of herbivorous metazooplankton. The Lofoten Basin (LB), on the other hand, is ice free during the whole year, but characterized by the early appearance of herbivorous metazooplankton during early spring.

While annual rates of nitrate use were comparable at the two sites (about 500 $\text{mmol N m}^{-2} \text{y}^{-1}$), seasonal patterns and the degree of coupling between the two rates were obviously different.

In the JMC the growth season started about two months earlier than at the LB and about 75 % of the annual new production took already place under partly ice covered and meltwater stabilized conditions. Early stabilization of the water column enabled this early onset of the growth season; variable ice coverage and hence variable light conditions until June-July, however, explained lower nitrate use and the longer duration of the spring phytoplankton development, as compared to other ice edge blooms, for instance in the Barents Sea. Contradicting to the classical scheme of phytoplankton succession, diatoms appeared to be less important as agents of new production during spring. As

evident from an analysis of seasonal silicate and nitrate disappearance rates non-silicious flagellates, particularly *Phaeocystis pouchetii*, are suggested to contribute significantly to new production under partly ice covered conditions in spring. Seasonal rates of new and export production were to a certain extent decoupled. Export production rates during summer, for instance, were 3 to 4 times as high than new production rates.

Seasonal rates of new and export production at the LB site were similar between late May and early September and appear to be strongly coupled. The grazing activity of herbivorous copepods, as documented at the nearby Voering Plateau, is discussed as a mechanism controlling the slow decrease of new nutrients at the surface and the strong coupling of new and export production.

Different seasonal patterns of quantity and quality of winter mixed layer (WML) export, as evident from sediment trap measurements at 500 m depth, were observed at the two study sites. In the JMC fluxes of PON and carbon increased significantly from winter levels in May-June. Large fluxes of particulate silicate, high numbers of diatoms, a significant fraction of them being viable, are discussed as indications for the importance of diatom aggregates as vehicles of deep fluxes of organic matter in the JMC. Faecal pellets appeared to be of less importance for deep POC flux, particularly in June-July. 'Excess POC fluxes', as calculated by the difference between POC flux and the Redfield equivalent of the PON-flux, were low throughout the whole year as compared to the LB-site. At the LB site fluxes of PON and carbon are low until mid of August. Mainly during September and October a significant increase in carbonate and 'excess POC flux' but not in PON or POC sedimentation was observed. Grazing activity of copepods on faecal pellets (coprophagy and coprohexy) are discussed to explain the low sedimentation rates and the high midwater recycling of organic matter during spring and summer. Autumn sedimentation events, such as those observed in the LB, have been attributed to the sinking of the pteropod *Limacina retroversa*³⁶⁰.

Although rates of annual new production and deep POC export were similar at the two study sites, seasonal coupling and the mechanisms that controlled the processes appeared to be quite different.

360 Bathmann et al. 1990; Honjo, 1990

Phyto- and protozooplankton biomass during austral summer in surface waters of the Weddell Sea and vicinity*

Eva-Maria Nöthig¹, Bodo von Bodungen² and Qingbo Sui³

¹ Alfred-Wegener-Institut für Polar- und Meeresforschung, Am Handelshafen 12, W-2850 Bremerhaven, Federal Republic of Germany
² Institut für Meereskunde, Düsternbrooker Weg 20, W-2300 Kiel, Federal Republic of Germany
³ Shandong College of Oceanography, Qingdao, P. R. China

Received 12 September 1990; accepted 14 April 1991

Summary. Phyto- and protozooplankton were sampled in the upper 10 m of the water column in austral summer during a cruise of *RV Polarstern* from January 6 to February 20 1985 in the eastern Bransfield Strait vicinity and in the northern, southeastern (off Vestkapp, twice: I and II) and southern Weddell Sea (Vahsel Bay across the Filchner Depression to Gould Bay). The plankton assemblages are discussed in relation to physical, chemical and biological factors in the different geographical areas in summer. Phytoplankton biomass (Phytoplankton carbon, PPC) ranged from 4–194 μg carbon/l and consisted on average of 65% diatoms and 35% autotrophic flagellates. Whereas in the northwest phytoplankton assemblages were dominated by small nanoflagellates (78% of PPC), higher biomass of diatoms (54–94% of PPC) occurred at the other sampling sites. In general autotrophic flagellates and small pennate diatoms dominated at oceanic stations; in neritic areas large centric diatoms prevailed. Chlorophyll *a* concentrations ranged from 0.25–3.14 μg chl *a*/l with a mean of 1.13 μg chlorophyll *a*/l and an average phytoplankton carbon/chlorophyll *a* ratio of 39. Protozooplankton biomass (Protozooplankton carbon, PZC) ranged from 0–67 μg carbon/l and consisted of 49% ciliates, 49% heterotrophic dinoflagellates and 2% tintinnids. Heterotrophic dinoflagellates were more important in the northern investigation areas (58%–84% of PZC). Ciliates dominated the protozooplankton in the southeast and south (56%–65% of PZC); higher abundances of tintinnids were observed only in the south (11% of PZC). The most remarkable feature of the surface waters was the high protozooplankton biomass: protozooplankton amounted to 25% on an average of the combined biomass of PPC plus PZC for the entire investigation period. Protozoan biomass in the southeastern and southern Weddell Sea occasionally exceeded phytoplankton biomass. Temperature, salinity, and inorganic nutrients were generally lower in the southern regions; at most of these stations a meltwater layer occurred in the upper meters of

the water column. We suggest that this physical regime allows a well developed summer system with a high proportion of heterotrophic microplankton. In the eastern Bransfield Strait, in the northern Weddell Sea and close to the coast off Vestkapp (I), however, early summer conditions occurred with less protozooplankton contribution.

* Contribution no. 427 from the Alfred-Wegener-Institute for Polar and Marine Research

Sediment traps in marine ecological research and
monitoring

**MACROZOOPLANKTONIC INFLUENCE ON THE FATE OF
PARTICLES IN THE OCEAN ***

Thomas T. Noji
Institute of Marine Research
P. O. Box 1870 Nordnes
N-5024 Bergen, NORWAY

ABSTRACT

Macrozooplankters can mediate the production, destruction and modification of particles in the ocean and, thus, can enhance or inhibit vertical particulate flux as well as modify the quality of sedimenting particles. With respect to feces, three important processes influencing the fate of particles are coprophagy, coprorhexy and coprochaly, which are the ingestion, fragmentation and loosening of fecal material, respectively. Coprophagy directly promotes the remineralization and respiration of fecal material. Coprorhexy and coprochaly reduce the sinking velocities of fecal particles, i.e. increase the pelagic residency time, increase particle substrate for aerobic microbes and presumably enhance processes of diffusion between the particle interior and the fluid medium. In all three cases the vertical particulate flux of material can be significantly reduced.

Kristineberg Marine Biological Station
Fiskebäckskil, Sweden
21-25 November 1990

THE INFLUENCE OF MACROZOOPLANKTON ON VERTICAL PARTICULATE FLUX

THOMAS T. NOJI

SARSIA



NOJI, THOMAS T. 1991 07 10. The influence of macrozooplankton on vertical particulate flux. - *Sarsia* 76:1-9. Bergen. ISSN 0036-4827.

The influence of macrozooplankton on sedimentation is quantitative and qualitative. As large particles are often the prime vehicles of vertical flux, macrozooplankters enhance rates of sedimentation by their production of carcasses, hard bodily parts and aggregates including fecal material. This may be promoted by vertical movements of zooplankton stocks. Macrozooplankton-regulated processes which enhance the recycling of pelagic material and thereby inhibit sedimentation are the physiological utilization of particulate organic matter and the destruction of aggregates, both of which promote the retention of essential elements and organic compounds in the upper productive water layers. In addition, the composition of sedimenting material is influenced by macrozooplankton through the composition of zooplankton stocks, discriminant feeding, selective metabolic utilization of ingested material and the biological and physicochemical properties of fecal material and other aggregates.

Thomas T. Noji, Institute of Marine Research, P.O.Box 1870, N-5024 Bergen-Nordnes, Norway.

IMAGE ANALYSIS OF FAECAL MATERIAL GRAZED UPON BY THREE SPECIES OF COPEPODS: EVIDENCE FOR COPRORHEXY, COPROPHAGY AND COPROCHALY

THOMAS T. NOJI, KENNETH W. ESTEP

Institute of Marine Research, PO Box 1870, 5024 Bergen-Nordnes, Norway

FERREN MACINTYRE

A/S Pixelwerks, Strandkaien 18/20, PO Box 1008, 5001 Bergen, Norway

FREDRIKA NORRBIN

Norwegian College of Fishery Science, University of Tromsø, Dramsøvn 201 B, 9000 Tromsø, Norway

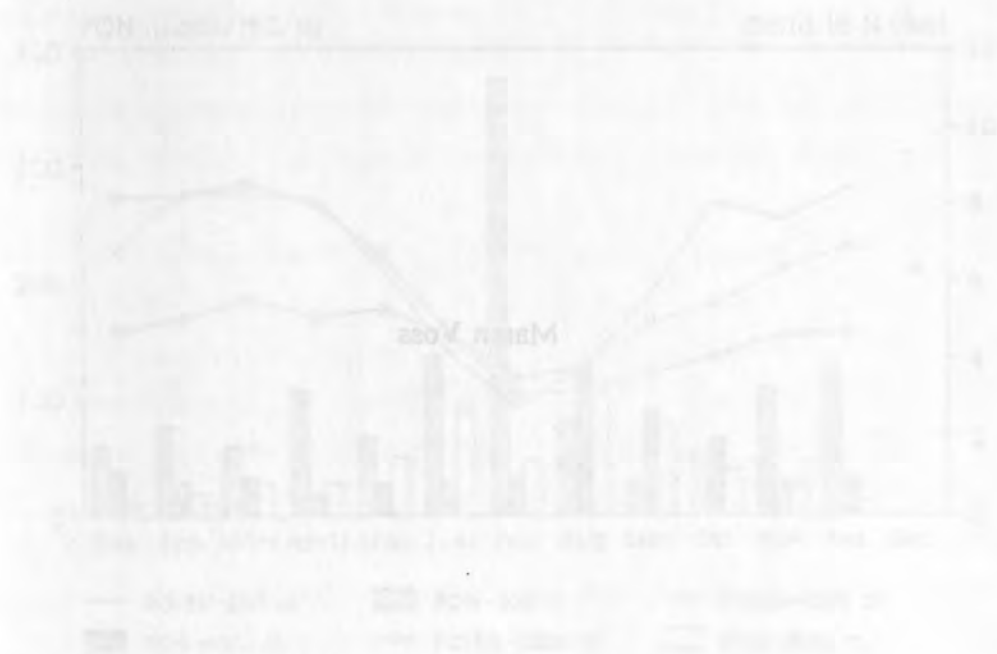
Experiments involving three species of copepods (*Acartia clausi* Giesbrecht 1889, *Pseudocalanus elongatus* Boeck 1872 and *Calanus finmarchicus* Gunnerus 1765) incubated with freshly produced copepod faecal material were conducted and analyzed using automatic image analysis. For two species (*A. clausi* and *C. finmarchicus*) the bulk of faecal material was not ingested but was fragmented. This process, coprorhexy, was accompanied by a shift toward smaller particles in the particle size-spectrum. Increases in total volume of the faecal particles after incubation with these copepods led us to propose a process which we refer to as 'coprochaly', derived from the Greek χαλασσω, (a loosening, as of bandages). Coprochaly was promoted by manipulation of the faecal material by the copepods. For the third species (*P. elongatus*), coprorhexy and coprochaly were coupled with coprophagy (ingestion of faecal material). Calculations indicated that the combined effect of coprorhexy and coprochaly reduced sinking velocities of the faecal particles by up to 50%. These processes increase pelagic residency time of particles, increase substrate area for aerobic microbes and presumably enhance remineralization of particulate organic matter.

Content of copepod faecal pellets in relation to food supply in Kiel Bight and its effect on sedimentation rate

Maren Voss

Institut für Meereskunde an der Universität Kiel, Düsternbroker Weg 20, W-2300 Kiel, Germany

ABSTRACT: The content of suspended and sedimented copepod faecal pellets in relation to phytoplankton stocks was investigated in Kiel Bight in summer 1986. Sedimentation rates of faecal pellets were also measured using sediment traps. Parallel to the field investigation, incubations were conducted in which the dominant copepods, *Acartia* sp. and *Centropages hamatus*, were fed with natural phytoplankton. Faecal pellets from field samples and laboratory experiments were analyzed by scanning electron microscopy. Results showed a strong relationship between the composition of ambient food supply, ingested phytoplankton and faecal pellet content. In addition, faecal pellet sedimentation rates in July and August (4400 and $7700 \text{ m}^{-2} \text{ d}^{-1}$ respectively) differed from those in September ($168\,000 \text{ m}^{-2} \text{ d}^{-1}$). This was attributed to the change in phytoplankton composition, which consisted mainly of athecate flagellates in July and August but was dominated in September by *Prorocentrum minimum*, a thecate dinoflagellate.



Nr. 32

**Räumliche und zeitliche Verteilung stabiler Isotope
($\delta^{15}\text{N}$, $\delta^{13}\text{C}$) in suspendierten und sedimentierten Partikeln
im Nördlichen Nordatlantik**

Maren Voss

geschaltet, so daß veränderte Isotopenwerte im sedimentierten Material vorliegen (geringfügige Kopplung). Wichtig hierbei sind Aggregationsprozesse, z.B. Grazing, die zu größeren, dichteren Partikeln und demzufolge sinkenden Partikeln in der euphotischen Zone führen. Um auf diese Prozesse rückschließen zu können, die die Aggregation bedingt hat, ist die Mikroskopie des sedimentierten Materials sehr hilfreich (Deuser 1987b, Bathmann et al. 1990, und Michaels et al. 1990). Aus den Daten ist eine POC- und PON- Abschätzung jedoch nicht immer möglich und die Übertragung der Befunde auf andere Parameter, z.B. die Isotopendaten, begrenzt. Schon geringe Anteile sedimentierten Materials können durch eine charakteristische Zusammensetzung das Gesamtsignal verändern (Banse 1990). Das gilt mit Sicherheit für stabile Isotope. Wenn die isotopische Modifikation z.B. durch Abbauprozesse nicht bekannt ist, können zu den Zeiten geringer Kopplung aus dem sedimentierten Material auch keine Rückschlüsse auf Prozesse in der euphotischen Zone gezogen werden. Umgekehrt sind Isotopendaten im SSF Material interpretierbar, wenn isotopisch bekannte Aggregationsprozesse zu rasch sinkenden Partikeln führen.

7.5. Schlußbetrachtung

Das Sedimentationssignal im Jahresgang wird zusammen mit den lückenhaften Informationen über Isotopendaten aus der Wassersäule und den vollständigeren Informationen über die sich saisonal wandelnden biologischen Vorgänge im Nordmeer betrachtet. Obwohl die Unterteilung der Partikel in 2 Gruppen, suspendierte und sedimentierte, wahrscheinlich eine starke Vereinfachung ist und es einen fließenden Übergang von kaum über langsam zu schnell sinkenden Partikeln gibt, möchte ich diese Einteilung übernehmen. Sie wird von vielen Wissenschaftlern benutzt (Deuser 1987a, Altabet 1988, Karl et al. 1988).

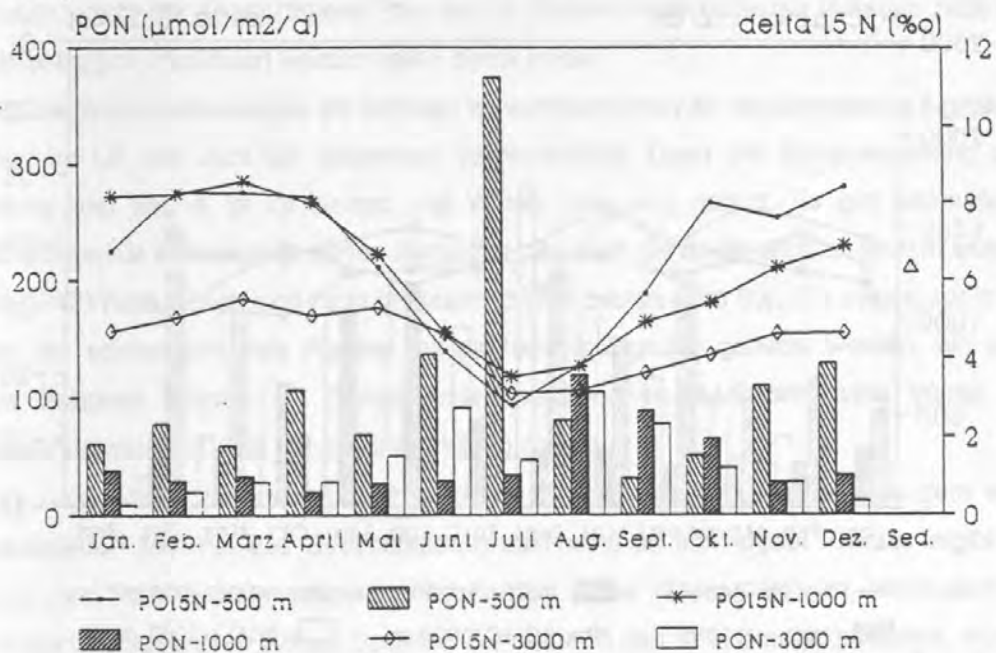


Abb.59 Zusammenstellung aller Monatsmittelwerte der Sedimentation partikulären organischen Stickstoffs (PON) und der dazugehörigen $\delta^{15}\text{N}$ Werte aus 3 Tiefenhorizonten, 500 m vom VP, 1000 und 3000 m der NB Verankerung. Das \triangle zeigt den mittleren $\delta^{15}\text{N}$ Wert des Sediments der JM und LB Stationen.

In beiden Partikelgruppen wurde ein saisonales Muster gefunden. Die Wechselwirkung zwischen den beiden Partikelgruppen ist jedoch nicht direkt, sondern man muß zwischen den zuvor beschriebenen Phasen enger Kopplung, d.h. direktem Export gebildeten Materials und Phasen mit geringem und verzögertem Fluß von Partikeln aus der euphotischen Zone unterscheiden.

Das ^{15}N -Sedimentationssignal von Mai bis Juli/August rührt hauptsächlich von der sukzessiven Fraktionierung bei der Nitrataufnahme her (Kap.7.1.). Da die Wachstumsperiode ausschließlich neuer Produktion kurz ist, ist auch der Zeitraum geringer Isotopenwerte nur wenige Monate lang. Doch schon gleich nach Wachstumsbeginn sedimentiert offenbar ein geringer Teil aus der saisonalen Deckschicht. Denn in den $\delta^{15}\text{N}$ Werten der NB Proben zeichnet sich 1987 und 1988 ein deutlicher Abfall von 8-9 ‰ auf 1-4 ‰, ein Fangintervall vor dem Maximum des Massenflusses ab. In den berechneten Monatsmittelwerten, die nicht den abrupten Abfall auf geringe $\delta^{15}\text{N}$ Werte zeigen, bildet sich der von Jahr zu Jahr variable Beginn und Verlauf des Frühjahrswachstums ab. Gleichzeitig belegt der identisch verlaufende Abfall der Werte von April bis Juli in 500 und 1000 m Tiefe, daß schnell sinkende Partikel, wie Kotballen oder Phytoplanktonaggregate, beteiligt sein müssen. Und auch in 3000 m Tiefe wurde bei geringerem Abfall der Isotopengehalte im Juli ein Mittelwert von 3,1 ‰ gemessen, in den anderen Tiefenstufen waren es 3,5 ‰ (1000 m) und 2,7 ‰ (500 m, Anhang Tab.10). Diese im Juli sedimentierte Menge stellt 20 - 30 % der Jahressedimentation des PON dar und resultiert aus einem direkten Export aus der euphotischen Zone.

Anders verläuft die Kopplung zwischen saisonalen Deckschichtprozessen und dem Partikelfluß die restliche Zeit des Jahres. Von Juli/August bis Dezember erfolgt ein unterschiedlich starker Anstieg

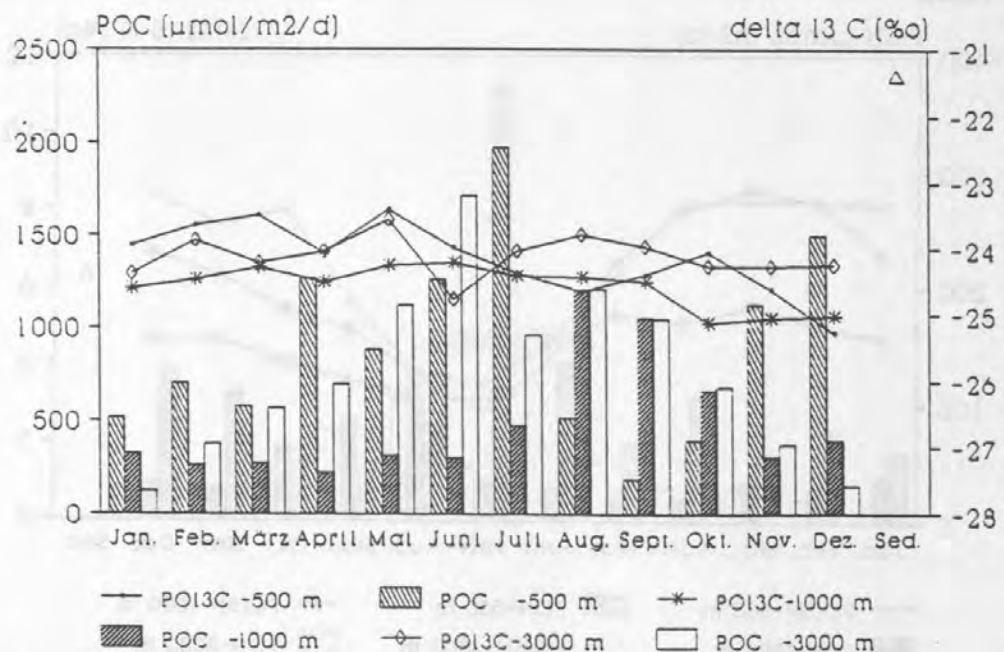


Abb.60 Zusammenstellung aller Monatsmittelwerte der Sedimentation partikulären organischen Kohlenstoffs (POC) und der dazugehörigen $\delta^{13}\text{C}$ Werte aus 3 Tiefenhorizonten, 500 m vom VP, 1000 und 3000 m der NB Verankerung. Das Δ zeigt den mittleren $\delta^{15}\text{N}$ Wert des Sediments für die LB und JM Stationen.

der $\delta^{15}\text{N}$ Werte in den betrachteten Tiefenhorizonten (Abb.59). Für das Zustandekommen dieses Verlaufs werden 2 Hypothesen vorgestellt:

1. Es erfolgt eine ständige langsame Sedimentation von Material aus der euphotischen Zone, das im Laufe der Wachstumsperiode isotopisch immer schwerer wird. Ursachen für die Zunahme der $\delta^{15}\text{N}$ Werte sind die Fraktionierung bei der Nitrataufnahme und Abbauprozesse, die bereits mehrfach erläutert wurden (Kap.7.2.). Aus diesem Grunde nehmen die $\delta^{15}\text{N}$ Werte in den SSF Proben kontinuierlich zu. Offen bleibt hierbei die Frage, warum in größeren Tiefen das sedimentierte Material wieder isotopisch leichter wird.
2. Das im Juli sedimentierte Material disaggregiert teilweise auf dem Weg in die Tiefe und verringert damit seine Sinkgeschwindigkeit. Aus diesem Pool wird in den folgenden Monaten die Sedimentation gespeist. Gestützt wird diese Hypothese durch die Berechnung eines mittleren gewichteten Jahres - $\delta^{15}\text{N}$ - Wertes (berechnet aus der monatlichen PON- und $\delta^{15}\text{N}$ Sedimentation). Sie ergibt für 500 und 1000 m Tiefe 5,64 ‰, für 3000 m Tiefe 4,17 ‰. Diese Zahlen unterscheiden sich nur um 1,5 ‰, und zeigen somit an, daß in allen Tiefenhorizonten auf Jahresebene eine vergleichbare Isotopenmenge ankommt. So ist keine unerklärbare Modifikation der Isotopenwerte mit der Tiefe erforderlich. Durch eine völlig anders angelegte Untersuchung unterstützen die Arbeiten von Karl et al. (1988) und Cho und Azam (1988) die 2. Hypothese. Die Autoren stellten wenig mikrobielle Aktivität auf sinkenden Partikeln fest und schreiben den Abbau in der Wassersäule nicht den an Partikeln angehefteten Bakterien sondern den freilebenden Mikroben zu. Bakterien sollen demnach eher den suspendierten Partikelpool, der wesentlich größer als der sinkende ist, abbauen (Cho und Azam 1988). Dies unterstützt die Erklärung der hohen Isotopengehalte in der Wassersäule im Herbst, die sich zuerst in den SSF Daten in 500 m Tiefe abbilden und nur langsam zu höheren $\delta^{15}\text{N}$ Werten in größeren Tiefen führen. Warum jedoch der disaggregierte Pool des im Frühjahr sedimentierten Materials nicht im Laufe der Monate isotopisch modifiziert werden sollte, bleibt unklar.

Das Sedimentationsereignis im Sommer ist wahrscheinlich für die isotopische Signatur in den SSF Proben im LB von Juni bis Dezember verantwortlich. Denn der Zusammenhang zwischen Partikelbildung und Export ist im Herbst und Winter nicht eng genug. Es gibt vermutlich wenig aggregationsfördernde Prozesse in dieser Jahreszeit, die auch die Sedimentation fördern würden.

Die $\delta^{13}\text{C}$ Werte lassen sich nicht in diesem Sinne deuten (Abb.60). Sie zeigen nur in wenigen Situationen, wo schnell sinkende Partikel mit eindeutiger Signatur gebildet werden, ein deutbares Signal. Als Beispiele können die Diatomeensedimentation im JM-Strom (hohe Werte) und die Kotballensedimentation auf dem VP (niedrige Werte) dienen.

Das suspendierte Material stammt wahrscheinlich, zumindest teilweise, aus dem sinkenden und disaggregierten Material des Sedimentationsmaximums im Juli/August. Daraus ergibt sich ein Widerspruch zum Schicksal der suspendierten Partikel in der Wassersäule im Jahresgang. Für sie wurde eine durch mikrobiellen Abbau bewirkte Zunahme in den $\delta^{15}\text{N}$ Werten postuliert. Für die aus demselben Material stammenden sedimentierten Partikel wurde jedoch keine isotopische Veränderung gefordert, um die isotopisch leichten Partikel in den SSF zu erklären. Eine Lösung kann nur die noch weitgehend unbekannte Wechselwirkung zwischen suspendierten und sedimentierten Partikeln im Meer sein. Beispielsweise könnten carnivore Zooplankter durch ihre Freßaktivität

isotopisch leichtes Material in Form von Kotballen produzieren. Diese Partikel würden abgereichertes Material in die SSF bringen. Inwieweit dies ein relevanter Prozess ist, kann zur Zeit nicht abgeschätzt werden. Ich möchte jedoch festhalten, daß aufgrund der Isotopenwerte der suspendierten Partikel eine mindestens einmalige Zufuhr neuen Materials pro Jahr gegeben sein muß. Dies steht im Gegensatz zu Arbeiten von McCave (1975) und Druffel und Williams (1990), die lange Verweilzeiten für suspendierte Partikel aufgrund ihrer Form und Masse vermuten und nach ^{14}C Altersdatierungen eine Turnoverzeit von ca. 10 Jahren angeben. Andererseits zeigen Messungen von Lipiden, Zuckern, Aminosäuren und Aminoazuckern einen Zusammenhang zwischen sinkenden und schwebenden Partikeln auf (De Baar et al. 1983, Ittekkott et al. 1984a und b, Wakeham und Canuel 1988). Sedimentiertes Material wurde allgemein eher durch Zooplankton - typische Verbindungen geprägt, suspendiertes dagegen von Zoo- und Phytoplankton. Die Bedeutung des Zooplanktons bei der Aggregation unterstreichen auch Ittekkott et al. (1984a). Eine Zunahme der Wachsester mit der Tiefe deutet ebenfalls darauf hin, daß Zooplankton beteiligt ist (Wakeham und Canuel 1988). Dieses Ergebnis kann jedoch nicht generell gelten, da beispielsweise eine absinkende Frühjahrsblüte keine Zooplankton-typischen Verbindungen tragen dürfte. Im suspendierten Material werden häufig viele labile Komponenten gefunden, die nur auf schnell sinkendes und kaum abgebautes Material schließen lassen (Wakeham und Canuel 1988). Die enge Interaktion zwischen schnell und langsam sinkenden Partikeln wird zuletzt auch durch Radioisotopenmessungen bestätigt (Bacon et al. 1985). Sie messen die Aktivität (Konzentration) von Mutter-Tochter Paaren radioaktiver Zerfallsreihen, die in gelöster bzw. an Partikel adsorbierter Form vorliegen. Daraus sind Rückschlüsse auf die Höhe des Exportes möglich. Bacon et al. (1985) stellen ein Modell auf, das eine ständige Wechselwirkung zwischen feinen und großen Partikeln im Meer fordert. Wahrscheinlich ist diese Wechselwirkung im Nordatlantik wesentlich intensiver als die nach diesen Daten vorgeschlagene einmalige Zufuhr "neuer" zu "alten" Partikeln pro Jahr. Um das jedoch zu belegen sind andere Methoden als die Messung stabiler Isotopen nötig (Voß et al. 1989). Diese Arbeit liefert einen Hinweis auf die hohe Dynamik der Partikel-Interaktionen zwischen der Oberfläche und 3000 m Wassertiefe innerhalb eines Jahres. Im Zusammenhang mit Lipidmessungen, Pigmentuntersuchungen und Mikroskopie werden die einzelnen Prozesse, die zur Sedimentation führen bzw. suspendierte Partikel produzieren, wesentlich genauer beschreibbar sein.

Sediment traps in marine ecological research and monitoring

PATTERNS OF PRODUCTION AND SEDIMENTATION IN THE NORWEGIAN COASTAL ZONE, THE BARENTS SEA AND THE NORWEGIAN SEA*

Paul Wassmann
Norwegian College of Fishery Science
University of Tromsø
N-9000 Tromsø, NORWAY

Rolf Peinert
Institut für Meereskunde
Düsternbrookerweg 29
D-2300 Kiel 1, F.R.G.

Victor Smetacek
Alfred-Wegener-Institut für Polar- und Meeresforschung
Am Handelshafen 12
D-2850 Bremerhaven, F.R.G.

INTRODUCTION

Pelagic systems are potentially capable of retaining and recycling all autochthonous organic material, although, some losses due to sinking particles inevitably occur. Relating processes in the surface layers quantitatively to vertical particle flux is difficult because only a small percentage of the total production is lost annually via sinking in the open ocean. Further, only a few types of particles contribute to this flux and only a small proportion of these may actually reach greater depths.

Measurements of vertical flux with sediment traps indicate spatial and temporal variations that reflect imbalances in the relationship between processes of particle formation and degradation. The most extensive data base has

Kristineberg Marine Biological Station
Fiskebäckskil, Sweden
21-25 November 1990

Edited by:
Paul Wassmann, Anna-Stiina Heiskanen & Odd Lindahl

Patterns of production and sedimentation in the boreal and polar Northeast Atlantic

PAUL WASSMANN, ROLF PEINERT and VICTOR SMETACEK



Wassmann, P., Peinert, R. & Smetacek, V. 1991: Patterns of production and sedimentation in the boreal and polar Northeast Atlantic. Pp. 209-228 in Sakshaug, E., Hopkins, C. C. E. & Øritsland, N. A. (eds.): Proceedings of the Pro Mare Symposium on Polar Marine Ecology, Trondheim, 12-16 May 1990. *Polar Research* 10(1).

Pelagic systems are potentially capable of retaining and recycling all autochthonous organic material, although some losses due to sinking particles inevitably occur. Relating processes in the surface layers quantitatively to vertical particle flux is difficult because only a small percentage of the total production is lost annually via sinking in the open ocean. Further, only a few types of particles contribute to this flux and only a small proportion of these may actually reach greater depths.

Measurements of vertical flux with sediment traps revealed seasonal and regional patterns also within the northwestern Atlantic and indicate imbalances between particle formation and degradation. The classical pattern of spring bloom sedimentation followed by reduced loss rates has been found in shelf and shallow water regions such as the Norwegian Coastal Current and fjords and is also encountered in the Barents Sea. In the Norwegian Sea, however, the seasonal pattern appears different as the seasonal maximum has been observed during late summer/autumn.

The physical environment determines nutrient availability and hence the particles potentially available for sedimentation. The relationship between phyto- and zooplankton governs vertical flux seasonality, and zooplankters with different life cycles and feeding strategies further modify the principle patterns. Herbivores with life-cycle strategies involving overwintering of large biomass and predictable seasonal appearance (copepods, euphausiids) will have a different impact than opportunistic organisms with very low overwintering biomass, for example salps and pteropods. The latter exhibit much greater interannual biomass variation and may thus contribute to interannual variability of the vertical flux. Shelf systems of similar latitude are generally comparable with respect to their flux patterns and also share similarities with marginal ice zones. Open ocean systems as the Norwegian Sea, however, exhibit different patterns which are similar to the subarctic Pacific.

Paul Wassmann, Norwegian College of Fishery Science, University of Tromsø, P.O. Box 3083 Guleng, N-9001 Tromsø, Norway; Rolf Peinert, Institut für Meereskunde, Düsterbrookweg 20, D-2300 Kiel 1, Federal Republic of Germany; Victor Smetacek, Alfred-Wegener-Institut für Polar- und Meeresforschung, Am Handelshafen 12, D-2850 Bremerhaven, Germany.

For. Sonderforschungsbereich 313, Univ. Kiel	Nr. 36	S. 1-150	1.2.1992
--	--------	----------	----------

Teilprojekt A2:

PROZESSE UND BILANZEN DES SEDIMENTTRANSPORTS

Kurzfassungen

Hochakkumulationsgebiete am norwegischen Kontinentalschelf:
Sedimentologische Abbilder Topographie-geführter Strömungsmuster

Frank Blum

Nr. 36

Hochakkumulationsgebiete am norwegischen Kontinentalhang:

Sedimentologische Abbilder Topographie-geführter Strömungsmuster

Frank Blaume

Diese Arbeit wurde im Rahmen des Sonderforschungsbereiches 313, Teilprojekt A2, angefertigt und beschäftigt sich mit dem Sedimenttransport im Bereich der Hochakkumulationsgebiete am Kontinentalhang des östlichen Europäischen Nordmeeres. Die Bathymetrie und Verteilung der Sedimentmächtigkeiten in den Untersuchungsgebieten wurden zunächst mit dem 3,5 kHz-Sedimentecholot flächenhaft kartiert, um anschließend die Sedimente gezielt mit langen und kurzen Sedimentkernen zu beproben. Die Datierung der Sedimentabfolgen mit der Sauerstoff-Isotopen-Stratigraphie erbrachte Holozän-Mächtigkeiten von 6 m sowie bis zu 10 m für Sedimente der Termination I im etwa 25 km*25 km großen Hochakkumulationsgebiet vor Gamlembanken (67°00'N und 7°45'E). Korngrößenanalysen zeigen, daß maximale Sedimentationsraten bis zu 65 cm/ky in den holozänen, siltigen Tonen vor Gamlembanken im Zentrum einer annähernd kreisrunden Kartiereinheit hauptsächlich durch die Akkumulation der Korngrößenfraktion < 20 µm zustande kommen. Die ebenfalls feinkörnigen, mit IRD durchsetzten, tonig-siltigen Schlämme der Termination I dagegen werden mit einer hangnormalen, horizontalen Gradierung in zwei "Sedimentationskanälen" mit Sedimentationsraten bis zu 230 cm/ky abgelagert.

Die Sauerstoff- und Kohlenstoff-Isotopenkurven aus den Kalkschalen planktischer Foraminiferen fünf langer Sedimentkerne aus den Untersuchungsgebieten am Kontinentalhang enthalten, zeitlich hochaufgelöst, neben dem globalen Erwärmungstrend in der Termination I und dem zwischenzeitlichen Kälterückschlag in der Jüngeren Dryas weitere Feinheiten, wie z.B. eine zweigestufte Termination I_B und hohe Variationen in den Isotopen-Verhältnissen auch in den holozänen Oberflächensedimenten. Dieses wird durch die laterale Advektion von Foraminiferen aus isotopisch verschieden charakterisierten Liefergebieten in die Akkumulationsgebiete am Kontinentalhang erklärt.

In einer regionalen Vermessung der Hydrographie wurden saisonale und auch kurzzeitige Schwankungen der Attenuation in den intermediären und bodennahen, nepheloiden Schichten am Kontinentalhang über den Hochakkumulationsgebieten festgestellt. Auf dem westlichen Barents See-Schelf konnte eine Bodenwasserbildung nachgewiesen werden. Von dort fließen dichte Wassermassen als Trübestrome vom Schelf über den oberen Kontinentalhang bis in die Tiefsee, wo sie für eine Modifizierung der Tiefenwassermassen sorgen können. Die Ursachen für die Attenuationsanomalien am mittelnorwegischen Kontinentalhang dagegen liegen in der Wechselwirkung von Grenzschichtwellen zwischen den Wassermassen des Norwegen Stromes (NAW) und dem Norwegen See Tiefenwasser (NSDW) begründet. Am Kontinentalhang topographisch gefange, zyklonale Wirbelstrukturen sind hier für die regionale Verbreitung der rezenten, bodennahen Trübezone prägend, was in geologischen Zeiträumen zur holozänen, nahezu kreisrunden Sedimentakkumulation geführt hat.

Durch die Kombination der Ergebnisse aus den Isotopendaten, der regionalen Korngrößenanalyse in den Terminationssedimenten und der hydrographischen Vermessung einer ozeanographischen ähnlichen Situation an der Polarfront vor dem Barents See-Hang, wurde versucht, die paläoozeanographischen Verhältnisse während der Termination I am Kontinentalhang vor Gamlembanken zu rekonstruieren. Danach stehen in der Termination I nach dem Rückzug des Schelfeises hangnormale Sedimenttransport-Prozesse in einer nur schwach stratifizierten Wassersäule im Vordergrund, die von der Hydrographie (Bodenwasserbildung, Schmelzwasser-Suspension) auf dem damals subpolaren Schelf nahe der Eiskante gesteuert wurden. Die Sedimente aus den Hochakkumulationsgebieten am Kontinentalhang des östlichen Europäischen Nordmeeres erlauben generell Rückschlüsse auf klimatisch induzierte Variationen der kontinentalen Eisschilde im Verlauf der letzten Deglaziation.

Mitteilungen zur Kieler Polarforschung



Übersichten
Berichte
Projekte
Thesen
Nachrichten
Veranstaltungen

Hochakkumulationsgebiete am Norwegischen Kontinentalhang: Dokumente Topographie-geführter Strömungsmuster

Im Rahmen des Sonderforschungsbereiches 313 an der Universität Kiel wurden als Ergebnis mehrerer Forschungsreisen (Poseidon 142, 146, 181 und 196) sowie Meteor 17 und 21 spätquartäre Hochakkumulationsgebiete am norwegischen Kontinentalhang und am westlichen Barents See-Hang kartiert. Die engmaschige Probenahme mit langen Schwereloten und Datierung der Sedimentabfolgen in den ungestörten Ablagerungen erbrachte Mächtigkeiten von bis zu 6 m für die jetzige Warmzeit (Holozän) sowie bis zu 10 m für Sedimente der Termination I (Übergang von der letzten Eiszeit in die jetzige Warmzeit) im etwa 400 km² großen Hochakkumulationsgebiet vor Gamlembanken bei 67°00'N und 7°45'E (700 m bis 1.200 m Wassertiefe). Die siltig-tonigen Sedimente erreichen sehr hohe Akkumulationsraten (bis 65 cm/1000 Jahre) im Zentrum der annähernd kreisrunden Kartiereinheit; die Mächtigkeiten nehmen von dort mit steilen Gradienten radialsymmetrisch nach außen hin innerhalb weniger Kilometer ab. Die Hauptmasse der darunter liegenden Terminationssedimente - angeordnet in zwei "Sedimentationskanälen" - besteht ebenfalls aus feinkörnigem Schlamm mit sehr hohen Ablagerungsraten bis zu 230 cm/1000 Jahren.

Sedimentverteilung und -sortierung der holozänen Einheit weisen auf eine von der Topographie des Kontinentalhangs geführte Sedimentation aus der bodennahen Trübezone (bottom nepheloid layer=BNL) hin. Die Ergebnisse einer ozeanographischen Meßreihe der Forschungsreise Poseidon 181 stützen die Annahme, daß die Verbreitung der rezenten BNL und damit auch die Sedimentakkumulation am Meeresboden durch Wirbelstrukturen im Wasserkörper gesteuert wird, die wiederum als Folge der Wechselwirkung von der Topographie des Kontinentalhangs mit den vorherrschenden Strömungen zu deuten sind. Dagegen stehen in der Termination I typisch hangnormale Sedimenttransport-Prozesse im Vordergrund (Trübestrome) deren Antrieb in der Bodenwasserbildung auf dem zu diesen Zeiten subpolaren norwegischen Schelf zu sehen ist, welche für einen Export von dichtem sog. "Winterwasser" und damit für hochenergetische, bodennahe Transportprozesse über den äußeren Schelf und Kontinentalhang sorgte.

Die aus den Hochakkumulationsgebieten am Kontinentalhang des östlichen Europäischen Nordmeeres gewonnenen Informationen erlauben Rückschlüsse auf sich verändernde Transportprozesse in der Wassersäule. Damit ist es möglich, auf Variationen regionaler Strömungsmuster im Verlauf der letzten Enteisungsphase zu schließen und damit auch über klimatische Veränderungen innerhalb der letzten 20.000 Jahre Auskunft zu geben.

Frank Blaume, Jan Rumohr; Sonderforschungsbereich 313

Topographisch gesteuerter Sedimenttransport in hohen Breiten

Auf den Forschungsreisen Poseidon 181 und 196 sowie Meteor 21-4 wurden in Fortsetzung früherer Arbeiten Areale am norwegischen Kontinentalhang und am westlichen Barents See-Hang kartiert, die sich durch anormal hohe Mächtigkeiten von junger Sedimente auszeichnen (Hochakkumulationsgebiete). Die Vermessung der regionalen Hydrographie mittels ozeanographischer Meßmethoden und die Untersuchung der räumlichen Verbreitung und zeitlichen Veränderung der bodennahen Trübezone, der nepheloiden Schichten (BNL) im Einzugsgebiet dieser Hochakkumulationsgebiete des östlichen Europäischen Nordmeeres, sollte Aufschluß über die Entstehungsprozesse dieser Sedimentakkumulationen geben.

Auf dem westlichen Barents See Schelf konnten aufgrund ihrer charakteristischen Temperatur und Salzgehalts-Eigenschaften spezifisch dichte, weil kalt und salzreich, Bodenwassermassen nachgewiesen werden, die - kanalisiert durch submarine Kanäle am äußeren Schelf - als Trübestrome bodennah vom Schelf bis über den oberen Kontinentalhang strömten. Die durchgeführten Trübemessungen auf Vertikalprofilen durch die Wassersäule zeigen, daß diese Bodenwassermassen an Dichte-Sprungschichten in den freien Wasserkörper abheben und ihre mitgeführte Transportfracht in den Zwischenwasserkörper eintragen. Ist die Dichte ausreichend hoch, so können sie dagegen bodennah bis an den unteren Kontinentalhang (tiefer als 2000 m) absinken und dort Anomalien in der bodennahen Trübeschicht hervorrufen. Dieser Prozeß führt einerseits zu

einer Auffrischung des Tiefenwassers mit Sauerstoff, stellt andererseits aber auch einen nicht zu unterschätzenden Prozeß für den Import von Sedimentpartikeln in die Tiefsee dar.

Am mittelnorwegischen Kontinentalhang liegen die Ursachen für die mit der Trübungssonde kartierten Anomalien in den bodennahen Wasserschichten in der Wechselwirkung von Grenzschichtwellen zwischen zwei unterschiedlich charakterisierten Wasserkörpern begründet: dem nach Norden strömenden, warmen Atlantischen Wasser (NAW) an der Oberfläche und dem kalten Norwegen See Tiefenwasser (NSDW). Stehende Wellen führen dazu, daß zwischen 400 m und ca. 800 m Wassertiefe Sedimente am Kontinentalhang nicht zur Ablagerung kommen. Das hohe Energieniveau ermöglicht sogar Erosion von Sedimentpartikeln, welche letztlich hangab in größerer Wassertiefen transportiert werden, wo sie schließlich zur Ablagerung kommen. Seewärts Gamlembanken bei 67°N bestimmen von der Topographie des Kontinentalhangs "eingefangene", stationäre Wirbelstrukturen von etwa 20 - 30 km Durchmesser bis in den Tiefenwasserkörper hinein die regionale Verbreitung der bodennahen Trübezone, was im Verlauf der letzten 10.000 Jahren zu einer nahezu kreisrunden Ausbildung der holozänen Hochakkumulation geführt hat.

Frank Blaume, Sonderforschungsbereich 313

Vorläufige Ergebnisse eines Transektes entlang des Kolbeinsey-Rücken

Eines der zentralen Arbeitsgebiete der METEOR-Reise 21-5 war der Kolbeinsey Ridge. Seine Lage zwischen dem Ostgrönland- und dem Ostislandstrom läßt ein deutliches Signal im bodennahen Partikeltransport und den benthischen Siedlungsmustern erwarten. Basierend auf Voruntersuchungen von Sedimentologen und Mikropaläontologen wurde ein Profil auf 67° 55'N mit insgesamt 7 Stationen ausgewählt und in einem interdisziplinären Arbeitsprogramm beprobt. Erste Ergebnisse lassen eine epibenthische Fauna auf der Westflanke gegenüber einer dominanten Infauna auf der Ostflanke des Rückens abgrenzen. Profile des ATP- und Chlorophyllgehaltes sowie der mikrobiellen Aktivität zeigen einen deutlichen Unterschied in den Sedimenten der beiden Flanken und verdeutlichen den Einfluß der unterschiedlichen Besiedlungsmuster, was als Bestätigung der aufgestellten Arbeitshypothese gewertet wird.

Angelika Brandt, Karen von Juterzenka, Dieter Piepenburg; Institut für Polarökologie
Gerd Graf, Maren Köster, Peter Linke, Ursula Witte; Sonderforschungsbereich 313

Untersuchungen zum Sedimenttransport an quartären glazialen und interglazialen Sedimenten aus dem nördlichen Nordatlantik

Die Feinfraktion (< 63 µm Korngröße) und die Grobfraktion (> 63 µm Korngröße) von quartären Sedimenten aus dem nördlichen Nordatlantik werden hochauflösend in ihrer Korngrößenverteilung und Sinkgeschwindigkeitsverteilung gemessen.

Hierzu werden bei der Grobfraktion eine Sedimentationswaage und die Siebmethode eingesetzt. Die Feinfraktion wird ebenfalls mit einer Sedimentationswaage gemessen. Zusätzlich werden bei der Feinfraktion noch Analysen mit einem Lasergranulometer und einem Sedigraphen durchgeführt.

Die Ergebnisse dieser Messungen machen qualitative und quantitative Aussagen zur Probenzusammensetzung und zum Sedimenttransport möglich. Ziel dieser Arbeiten im Sonderforschungsbereich 313 ist ein Ansatz zur Bilanzierung der verschiedenen Faktoren der Sedimentakkumulation im nördlichen Nordatlantik (biogene Produktion von Sedimentpartikeln, Eistransport von Sedimentpartikeln und Strömungstransport von Sedimentpartikeln).

Klaus Michels, Sonderforschungsbereich 313

Kluwer Academic Press, in press.

SEDIMENTS AND LANDFORMS OF PAST GLACIAL ENVIRONMENTS:

GLACIO-MARINE ENVIRONMENTS (J. Neutès (ed.))

"ANCIENT GLACIOMARINE SEDIMENTS"

by

Anders Elverhøi* and Rüdiger Henrich#

*** Department of Geology, University of
Oslo, Box 1047, 0316 Oslo 3, Norway**

**# GEOMAR, Wischhofstr. 1-3, D-2300 Kiel
Germany**

CONTENT

INTRODUCTION	3
GLACIOMARINE SEDIMENTS: CLASSIFICATION AND IDENTIFICATION ...	4
Ice-rafted detritus	7
Grain-size distribution and sedimentation rate	8
Deep water formation	10
Sea ice cover	11
Circulation system/current regimes	12
Oxygen and carbon isotopes in glaciomarine settings	12
Carbonate sedimentation in glaciomarine environmental settings	14
Biogenic opal production and preservation in glaciomarine environmental settings	17
Carbonate dissolution records and early diagenetic reactions as a response to changing bottom water properties in glaciomarine settings	19
Ecologic conditions and environmental reconstructions	21
EXAMPLES OF PRE-CENOZOIC GLACIOMARINE SEQUENCES	23
Gowganda Formation	23
<u>Continental slope/channel fill</u>	24
<u>Resedimentation of glacially-transported debris</u>	25
<u>Ice proximal regime</u>	25
<u>Gowganda Formation - conclusive remarks</u>	26
Port Askaig Formation	26
<u>Sub-glacial origin</u>	27
<u>Glaciomarine formation</u>	28
<u>Port Askaig Formation - conclusive remarks</u>	29
GLACIOMARINE SEDIMENTS AND SEDIMENTARY ENVIRONMENT OF A PASSIVE MARGIN AND ITS ADJACENT OCEAN- EXEMPLIFIED BY THE NORWEGIAN-GREENLAND SEA AND THE NORWEGIAN/BARENTS SEA MARGIN	30
Cenozoic glaciations - general background	30
General aspects of the Late Cenozoic glaciomarine sedimentation of the Norwegian-Greenland Sea	32
Barents Sea/Northern Norwegian shelf	34
The continental slope	39
The deep sea environment	42
<u>General background</u>	42
<u>Facies succession</u>	43
<u>Environmental interpretations</u>	46
CONCLUSIONS	48
FIGURE CAPTIONS	50
REFERENCES	54

Chapter 18

GLACIOMARINE ENVIRONMENTS "ANCIENT GLACIOMARINE SEDIMENTS"

A. Elverhøi and R. Henrich

18.1 INTRODUCTION

The origin and genesis of ancient (pre-Holocene) glaciomarine sediments is still a subject of controversy (for definition of glaciomarine sediments see Chapter 13). Until recently, knowledge of modern glaciomarine sediments was limited, in comparison to that of terrestrial glacial deposits. Consequently, terrestrial glacial sediments were over-emphasized in studies of Cenozoic as well as pre-Cenozoic sediments. However, as information on modern environments has progressed, reinterpretations of ancient sequences have demonstrated that glaciomarine sediments are widespread (Anderson, 1983). Glaciomarine sediments are now well documented as an important constituent of all the major glacial episodes in the Early Proterozoic, Late Proterozoic (Late Precambrian), Paleozoic, and Cenozoic (Hambrey & Harland, 1981) (Chapters 2 & 20).

A basic problem in interpreting ancient glaciomarine sediments has been, and still is, the lack of reliable criteria for differentiating between marine and terrestrial glacial sediments. During the last two decades understanding of the glaciomarine environment has progressed significantly, in particular, with regard to the proximal ice regime, where detailed studies have been conducted (Powell, 1984; Dowdeswell & Scourse, 1990; Anderson & Ashley, 1991). For open marine conditions, and especially for glaciomarine sedimentation in the deep ocean, knowledge is still limited. However, new marine sampling techniques have provided a large number of undisturbed deep sea sediment cores. Hence, it has been possible to combine conventional methods of glaciomarine facies analysis with micropalaeontological and geochemical data analysis to interpret palaeo-oceanographic, ecologic and

glaciomarine processes. Furthermore, a high degree of stratigraphic resolution has become possible through the use of oxygen isotope stratigraphy and AMS ^{14}C dating.

It is now possible to identify the basic elements of an interglacial-glacial cycle within shelf, slope, and deep sea sediments (e.g., Henrich, 1990). In this chapter the glaciomarine sedimentary environment will be illustrated by data from Norwegian-Greenland Sea and the northern Norwegian slope and shelf, including the western Barents Sea (Fig. 18.1). In addition, two well-known Early and Late Pre-Cambrian sections will be described and discussed with regard to classical conflicts in interpreting ancient glaciomarine sediments.

18.2 GLACIOMARINE SEDIMENTS: CLASSIFICATION AND IDENTIFICATION

Traditionally, deep sea sediments have not been referred to in discussions of the glaciomarine environment (Chapter 13). However, progress in geological marine research has demonstrated that deep sea ~~pelagic~~ sediments represent an important source of information concerning the long term glacial record. In high latitude areas, the deposition of the deep sea sediments is largely controlled by the glacial conditions onshore and on the continental shelf, e.g., ice-shelf regimes, grounded ice-margins, tidewater glaciers. It is crucial to understand the origin of these sediments in the Cenozoic record in order to relate them to the correct glacial regime. 119

In the analysis of deep sea glaciomarine sediments, it is important to realize that many glaciomarine processes have daily and/or seasonal fluctuations, and the progradation or regression of glacial environments can occur on a scale of years to tens of years. In addition, shifts in pelagic sedimentation may occur, but on a much longer time-scale. Although seasonal pulses in pelagic particle flux within polar oceans are the rule, rather than the exception, the average pelagic accumulation rates are more continuous over longer periods, e.g. centuries or thousands of years; while glaciomarine sedimentation is generally characterized by fluctuating

CYCLES, RHYTHMS, AND EVENTS IN QUATERNARY ARCTIC AND ANTARCTIC GLACIOMARINE DEPOSITS

R. HENRICH

GEOMAR Forschungszentrum für Marine Geowissenschaften
Wischhofstraße 1-3
D-2300 Kiel 14, F.R. Germany

ABSTRACT. Highly variable facies patterns of sub-Arctic glaciomarine continental margin environments contrast with less pronounced variations in Antarctic deposits. Shallow portions of the sub-Arctic shelves reveal regressive facies successions comprising basal lodgement till and high energy reworked top sequences during glacio-isostatic uplift. Deeper portions of sub-Arctic shelves record advance/retreat cycles of continental ice with up to 150 m thick glacial units which are separated by glacial erosional surfaces. Greatest thicknesses occur on the shelf break and upper slope with depocenters situated at the mouth fans. Prograding slope sequences reveal a complex sigmoid-oblique seismic character formed by alternating build-up during glacial progradation and depositional bypass/erosion in the topset during interglacial periods. Antarctic shelf deposits reveal biogenic siliceous muds or gravelly diamictos with admixtures of a monogenetic biogenic epifauna deposited at low sedimentation rates.

Sub-Arctic and Antarctic deep-sea sediment records reflect glacial/interglacial variations in carbonate and opal productivity and ice-rafted debris input. In Norwegian - Greenland Sea's deep sea pelagic environments widespread distribution of dark diamictos indicates extensive advances of the continental ice-sheets onto the shelves and permits connection of open ocean with shelf records. In the Weddell Sea, glacial, transitional and interglacial facies patterns correspond to advance/retreat cycles of the Antarctic ice-sheet, episodic development of floating ice-shelves, variations in the extension of sea ice coverage and cyclic development of polynyas within the Weddell Sea sea ice-cover.

Introduction

Today the northern and southern polar and subpolar oceans and shelves are strongly influenced by glacial processes. Together with mountain glaciations, about 10% of the Earth's surface are covered by ice and snow. During the Cenozoic and also in earlier glacial periods, variations in magnitude and dimension of the Earth's ice and snow cover document repetitive shifts of global climate. Development of the Antarctic ice-cap in early Cenozoic time (Kennett, 1977) and onset of northern hemisphere glaciation in late Cenozoic time (Plafker & Addicot, 1976; Armentrout, 1983; Henrich *et al.*, 1989a, b and references therein) mark a progressive global cooling that is well documented in the climatic records of the oceans (Miller *et al.*, 1987). Superimposed on these long-term changes in the Earth's climate that correspond to specific plate tectonic and paleoceanographic settings are short-term changes that are primarily controlled by cyclic variations of the Earth's orbital parameters, *e.g.* Milankovitch cycles (Hays *et al.*, 1976).

The objectives of this chapter are manifold:

1. To provide an overview of the principal controls on glaciomarine deposition in continental margin environments
2. To discuss depositional events, cycles and rhythms in Subarctic and Antarctic Pleistocene glaciomarine sequences, and their significance for paleoceanographic and paleoclimatic reconstructions.
3. To compare high input (Subarctic) and low input (Antarctic) glaciomarine records.

1.1 Terminology of Glaciomarine Deposits

The most commonly used definitions of the varieties and subtypes of till are not merely descriptive, but incorporate aspects derived from theoretical modeling. Eyles et al. (1983) propose that glacial facies analysis should apply a purely descriptive nomenclature, which can be easily applied during field work as well as during core logging. Use of the term till (and tillite) should be reserved for sediments directly deposited at the base of a glacier by sub- and supraglacial aggregation of englacial debris, without subsequent reworking (Eyles et al. 1983). The term glaciomarine diamicton (and diamictite) can be employed for any poorly sorted gravel-sand-mud mixture (Frakes 1978), deposited directly or indirectly from ice in glaciomarine environments.

1.2 The Basal Thermal Regime: a Major Control on Glacial Deposition

The volume of diamicton and lithofacies sequences that is deposited by a glacier largely depends on its basal thermal regime. Three thermal or glaciodynamic basal regimes are often recognized at modern ice margins (Fig. 1).

1.2.1 Temperate Glaciers

The glacier may be wet-based and slide over its bed (e.g., Iceland, Boulton 1972; Alaska, Powell 1983; Powell and Molnia 1989). A typical vertical profile (Fig. 1A) reveals a wide range of diamicton, including basal lodgement till, deposited during traction over the bed, and melt-out diamicton interbedded and channeled with glaciofluvial facies. Erosional contacts, multiple diamictons with undulating geometry, thin stratified units released by subglacial melt-out, as well as resedimented diamictons released from drumlin slumps, are common features in temperate glacier lithofacies profiles.

6.8 Cycles, Rhythms, and Events on High Input and Low Input Glaciated Continental Margins

R. Henrich

1 Introduction

Today, oceans and shelves in the northern and southern hemispheres are strongly influenced by glacial processes. Together with mountain glaciations, about 10% of the Earth's surface is covered by ice and snow. During the Cenozoic, as well as in earlier glacial periods, variations in the magnitude and dimension of the Earth's ice and snow cover resulted in repetitive shifts of the global climate through changes in albedo and total ice volume. Development of the Antarctic ice cap in the early Cenozoic (Kennett 1977) and the onset of Northern Hemisphere glaciation in the late Cenozoic (Plafker and Addicott 1976; Armentrout 1983; Henrich et al. 1989 and references therein) mark a progressive global cooling that is well documented in the climatic records of the oceans (Miller et al. 1987). Superimposed on these long-term changes in Earth's climate – which correspond to specific plate tectonic and paleoceanographic settings – are short-term changes that are controlled primarily by cyclic variations in Earth's orbital parameters, e.g., Milankovitch cycles.

In addition to the Cenozoic, extensive glaciations are documented during other periods of Earth's history, such as the Proterozoic and the Permocarboneous Gondwana glaciations (Frakes and Crowell 1975). During the Pleistocene, more than 40% of the Earth's continental shelves were glaciated (Climap 1976, 1981). Glaciations also influence continental margins through sea level fluctuations, with the consequent migration of facies belts, changes in width of the continental shelves (Beard et al. 1982), and variations in the quantity and type of continental erosional products and sediment delivery to slope and deep sea environments (Ruddiman 1977; Thiede et al. 1986; Henrich et al. 1989). Glaciations indirectly influence nonglaciated continental margins by perturbing high level atmospheric circulation, with its associated variations in aeolian dust supply and oceanic productivity (Sarnthein et al. 1982; Stein 1986a).

Ancient glaciomarine sections have been studied extensively by numerous workers (see bibliography in Eyles et al. 1985 and Edwards 1986). Studies of modern glaciomarine environments were comparatively few until about 20 years ago, but much progress has been achieved since then. A summary of our knowledge on glaciomarine environmental settings has been compiled in a special volume on *Glaciomarine Sedimentation*, edited by B. Molnia (1983), and in special issues of *Marine Geology* (Volume 57, 1984; Volume 85, 1989).

Beckenanalyse des Europäischen Nordmeeres: Pelagische und glaziomarine Sedimentflüsse im Zeitraum 2.6 Ma bis rezent

Habilitationsschrift vorgelegt von Rüdiger Henrich

Christian - Albrechts - Universität - Kiel 1992

Beckenanalyse des Europäischen Nordmeeres: Pelagische und glaziomarine Sedimentflüsse im Zeitraum 2.6 Ma bis rezent

Gliederung

Zusammenfassung.....	1
1. Einleitung	
1.1. Darstellung des Forschungsansatzes.....	5
1.2. Becken/ Schelf-Topographie.....	7
1.3. Schlüsselgebiete der ozeanischen Zirkulation im Europäischen Nordmeer und angrenzenden N- Atlantik.....	10
1.4. Zeitskalen der geologischen und mikropaläontologischen Befunde.....	15
2. Methoden	
2.1. Kernentnahme und Datenermittlung an Bord	16
2.2. Labormethoden	
2.2.1. Sedimentologische Standardanalysen und Bearbeitungs- schema.....	18
2.2.2. Auswertung von Radiographien.....	20
2.2.3. Grobfraktionsanalyse.....	21
2.2.4. Mikropaläontologische Untersuchungsmethoden.....	23
2.2.5. Untersuchungen zum Erhaltungszustand polarer und subpolarer pelagischer Karbonate.....	24
2.2.6. Geochemische Analysen zum Redoxpotential des Gesamtsedimen- tes.....	30
2.2.7. Rock EVAL, $\delta^{13}\text{C}$ Messungen und organische Petrographie an der organischen Substanz.....	31
2.2.8. Sauerstoff/-Kohlenstoffisotopenstratigraphie.....	32
2.2.9. Quantifizierung der Sedimentflüsse	34
2.3. Anwendung des Fazieskonzeptes in pelagischen und glaziomarinen Sedimenten des Europäischen Nordmeeres	39

3. Pelagische, benthische und glaziomarine Prozesse: Auswahl geeigneter Signalträger und Interpretationskonflikte	
3.1. Pelagischer Partikelfluß.....	39
3.2. Benthosökosysteme und Organismenaktivitäten an der benthischen Grenze.....	46
3.3. Sedimenttransport durch Pack-(Meer-)eis versus Eisberg.....	50
3.4. Prozesse des lateralen Sedimenttransportes	60
3.5. Abgrenzung von Temperatur, Salinitätseffekten in den Sauerstoff- und Kohlenstoff- Isotopenverhältnissen planktischer Foraminiferen.	66
3.6. Veränderungen der Bodenwasser- und Porenwasser- Eigen- schaften.	69
4. Rezente pelagische und terrigene Sedimentflüsse im Europäischen Nordmeer.....	73
4.1. Karbonatproduktionszentren.	75
4.2. Opalproduktion und Erhaltung.	79
4.3. Eintrag organischer Substanzen.	80
4.4. Terrigener Sedimenteintrag.	81
5. Sedimentologisch- geochemische Charakteristik glazial / interglazialer Sedimentfazies in der Tiefsee.	82
6. Stratigraphische Korrelation der Tiefseesedimente des Euro- päischen Nordmeeres.	113
7. Raum / Zeitkonfigurationen pelagischer und glaziomariner Fazieskörper im offshore Bereich des Europäischen Nordmeeres.	124
8. Sedimentologisch- geochemische Charakteristik und paläo-ozeanographische Signifikanz rhythmischer und zyklischer Faziesabfolgen.	132

9. Regionale Verteilungsmuster pelagischer und glaziomariner Sedimentflüsse im Europäischen Nordmeer 400ka bis rezent.	148
9.1. Pelagische Karbonatproduktion und Erhaltung in Glazialen und Interglazialen.	148
9.2. Variabilität benthischer Faunenassoziationen in glazial/interglazialen Sedimenten des Europäischen Nordmeeres.	191
9.3. Variabilität der terrigenen Sedimentflüsse in Glazialen und Interglazialen.	196
10. Bilanzierung der langfristigen Variabilität des Eintrags pelagischer und glaziomariner Sedimentkomponenten während der letzten 2.6 My.....	220
10.1. Variabilität der pelagischen Karbonatproduktion und Erhaltung im Ostsektor des Europäischen Nordmeeres im Zeitraum 0.4 Ma - 2.56 Ma.	222
10.2. Variabilität der pelagischen Opalproduktion und Erhaltung im Ostsektor des Europäischen Nordmeeres während der vergangenen 2.56 Ma.	237
10.3. Variabilität des terrigenen Sedimenteintrags im Ostsektor des Europäischen Nordmeeres im Zeitraum 0.4 Ma - 2.56 Ma.	239
10.4. Variabilität benthischer Faunenassoziationen in den ODP- Leg 104 Bohrungen während der vergangenen 2.56 Ma.	255
11. Faziesspektren von glazialen und interglazialen Schelf und Kontinentalhangsedimenten.	256
11.1. Seismische Befunde und erste stratigraphische Einstufungen glazial/ interglazialen Schelfsequenzen des Europäischen Nordmeeres.	257
11.2. Holozäne Sedimentfazies der Schelfgebiete.....	259
11.3. Postglaziale Sediment- und Faunenabfolge auf den Schelfgebieten des Europäischen Nordmeeres.	262
11.4. Karbonat- Restsedimentdecken als Abbild paläo- ozeanographisch gesteuerter niedrig akkumulierender Karbonatproduktion auf den Schelfgebieten des Europäischen Nordmeeres.	

.....	264
11.5 Die Entwicklungsgeschichte holozäner Rotalgenriffe in der Schärenlandschaft Nordnorwegens: Abbildung jüngster Meeres- spiegelschwankungen.	267
12. Oberflächen- und Tiefenwasserzirkulationsmodelle des Euro- päischen Nordmeeres : eine vergleichende Diskussion.	271
13. Geschichte der Oberflächen- und Bodenwassermassen im Europäischen Nordmeer während der letzten 2.6 Ma.	280
13.1. Phase 3 (2.56 Ma - 1.2 Ma): Gemäßigt- glaziale Verhältnisse und relativ stabile, klein- dimensionierte Eisschilde in der Umrahmung des Europäischen Nordmeeres.	281
13.2. Phase 2 (1.2 Ma - 0.6 Ma): Verstärkung paläo -oceanogra- phischer Kontraste mit Zunahme des glaziomarinen Sedi- menteintrags in den Glazialzeiten und Einsetzen hoher pela- gischer Karbonatproduktion während der Interglaziale.	285
13.3. Phase 1 (0.6 Ma - rezent): Verstärkte meridionale Zirkula- tion auf der N - Hemisphäre mit breiten Intrusionen des Norwegenstromes in den Interglazialen und maximaler Effi- ziens glaziomariner Sedimentationsprozesse während der Glazialzeiten.	287
Literaturverzeichnis.....	316
Danksagung.....	344
Apendix:	
Verzeichnis der Abbildungen	
Verzeichnis themenrelevanter Publikationen des Autors.	

Zusammenfassung

Das Europäische Nordmeer ist eine der klimatisch- sensitivsten Regionen der Nordhemisphäre und zugleich eine der wichtigsten Steuerungszentralen der globalen ozeanischen Zirkulation. Heute wird von hier ein Großteil des Weltozeans mit sauerstoffreichem Tiefenwasser versorgt. Eine wichtige Voraussetzung hierfür bildet der Einstrom salzreicher atlantischer Oberflächenwassermassen auf der Ostseite des Beckens bei gleichzeitiger Ausbildung eines Kältepol in den westlichen und nördlichen Regionen mit einer Eiskappe über Grönland und einer Meereisdecke über dem Arktischen Ozean und seinen Randgebieten. Schon geringfügige Schwankungen des globalen Klimas können starke Veränderungen in der ozeanischen Zirkulation des Europäischen Nordmeeres verursachen.

Zahlreiche methodische Ansätze sind in den bisherigen Arbeiten verfolgt worden, um diese ozeanographischen und klimatischen Veränderungen zu beschreiben und in ihrer Wechselwirkung zu tektonischen Vorgängen und Schwankungen der Orbitalparameter der Erde zu verstehen. Dabei ergeben sich oft kontroverse Modellvorstellungen und widersprüchliche Aussagen. Da alle Einzelparameter aufgrund einer Vielzahl, sich oft überlagernder Prozesse resultieren, können verlässliche Aussagen nur durch einen synoptischen Vergleich, unter kritischer Abwägung der widersprüchlichen Einzelaussagen, getroffen werden. Unter diesem Aspekt mußten bei den vorliegenden Untersuchungen vielfach auch neue methodische Ansätze verfolgt werden.

Zu nennen sind:

- eine differentielle Bilanzierung der Grob- und Feinkornanteile der karbonatischen und terrigenen Sedimentbestandteile; die verschiedenen Anteile ermöglichen eine Abschätzung des Foraminiferenflusses (Grobkarbonat), des Nannoplanktonflusses (Feinkarbonat), des feinkörnigen terrigenen Suspensionseintrags u. a. durch Meereis (terrigenes Feinfraktion), sowie den Eintrag durch Eisbergfracht (Grobterrigenanteil).
- Kartierungen von Dropstoneprovinzen zur Rekonstruktion der Eisdriftströme.
- kombinierte kohlepetrographische und geochemische Untersuchungen am organischen Material zur Bestimmung mariner und terrigener Anteile.
- REM - Lösungsindices an planktischen Foraminiferen zur Charakterisierung des Erhaltungszustandes pelagischen Karbonates und zur Bestim-

mung der Bodenwasserkorrosivität.

Unter Anwendung des Prinzips des Aktualismus werden in der vorliegenden Arbeit zunächst die wichtigsten Signalträger der heutigen Oberflächenwassermassen in den Sedimenten definiert, und die rezenten pelagischen, benthischen und glaziomarinen Prozesse in ihrer Vernetzung diskutiert. Aufgrund einer vergleichenden Analyse sedimentologischer, mikropaläontologischer und isotopischer Parameter wird ein Fazieskonzept für die pelagischen und glaziomarinen Sedimentfolgen entwickelt, das es erlaubt, die verschiedenen Fazieskörper in ihrer räumlichen und zeitlichen Ausdehnung zu erfassen, und sie spezifischen Oberflächen- und Bodenwasserkonfigurationen zu zuordnen. Mittels charakteristischer Faziesabfolgen können somit paläo- ozeanographische Entwicklungen während der glazial/interglazialen Klimaschwankungen rekonstruiert werden. Anhand der Ergebnisse aus den Tiefsee- Sedimentkernen und von Schelfsedimenten sowie der klimatischen Befunde von den angrenzenden Landmassen wird die paläo- klimatische und paläo- ozeanographische Entwicklung der letzten 2.6 Ma in einem dreiphasigen Modell beschrieben:

- Phase 3 (2.56 Ma - 1.2 Ma): Gemäßigt glaziale Verhältnisse und relativ stabile, klein dimensionierte Eisschilde in der Umrahmung des Europäischen Nordmeeres mit einem episodischem Einstrom atlantischer Wassermassen in küstennahen Regionen Süd- und Mittelnorwegens.

- Phase 2 (1.2 Ma - 0.6 Ma): Verstärkung paläo- ozeanographischer Kontraste mit Zunahme des glaziomarinen Sedimenteintrags in den Glazialzeiten und Einsetzen hoher pelagischer Karbonatproduktion während der Wärmespitzen der Interglaziale.

- Phase 1 (0.6 Ma - rezent): Verstärkte meridionale Zirkulation auf der N- Hemispäre mit breitem Einstrom des Norwegenstromes in Interglazialen und maximaler Wirksamkeit glaziomariner Sedimentationsprozesse in den Glazialzeiten.

Phase 1 (0.6 Ma - rezent) ist durch hohe Kontraste zwischen besonders starken Glazialzeiten und warmen Interglazialzeiten charakterisiert, wobei eine große Variabilität der Oberflächen- und Tiefenwasserzirkulationsmustern beobachtet wird. Aufgrund der vorliegenden Ergebnisse wird ein den heutigen Verhältnissen entsprechendes modifiziertes antiästuarines Zirkulationsmodell auch für lange Phasen der Glazial-

zeiten angenommen. Da der Golfstrom jedoch in den Glazialzeiten meist schon im N- Atlantik nach Süden abgelenkt wurde, stellen sich beim Fortbestehen einer antiästuarinen Zirkulation sofort die Fragen nach ihrem Antrieb in der Oberflächenzirkulation sowie alternativen Mechanismen der Tiefen- und Zwischenwassererneuerung im Europäischen Nordmeer, die einen Tiefenwasserexport auch in den Glazialzeiten weitgehend aufrecht erhalten würden. Der Autor favorisiert eine von katabatischen Winden von den Eisschilden über Skandinavien/ N - Europa und Grönland/ N- Amerika angetriebene Oberflächenwasserzirkulation im Europäischen Nordmeer. Aufgrund von Klimamodellierungen zeigen Kutzbach & Guetter (1986) sehr ähnliche Zirkulationsmuster mit ortsfesten Hochdruckgebieten über den Eisschilden sowie Fallwinden in ihrer Umrahmung. Diese Fallwinde würden von der Corioliskraft auf der Ostseite des Europäischen Nordmeeres nach N und auf der Westseite nach S abgelenkt. Insgesamt würden somit Eisrand- parallele Driftströme die Stromsysteme des Norwegen- und des Grönlandstromes ersetzen. Starke N- Winde in der Framstraße würden den ostseitigen Driftstrom nach SW abdrehen und in das westseitige Stromsystem einspeisen. Je nach Stärke dieser N- Winde könnte das Abdrehen des Ostdriftstromes auch bereits weiter im S, beispielsweise am Barentsschelf erfolgen. Im Zentrum des Europäischen Nordmeeres würden ein oder mehrere zyklonale Wirbel, die beiden gegenläufigen Driftströme verbinden. Bei einer derartigen Oberflächenwasserzirkulation wäre eine saisonale Einspeisung von verdrifteten Atlantikwässern in den Ostrandstrom möglich. Zusätzlich könnten die Fallwinde offene Wasserflächen schaffen, die durch winterlichen Meereiszuwachs zu einer Tiefenwassererneuerung beitragen könnten. Durch die ablandigen Winde könnte es an den Eisrändern zu den auch im rezenten bekannten lokalen Auftriebserscheinungen kommen.

Im Detail wird eine große Variation an glazialen und interglazialen Oberflächenwasserzirkulationsmuster beobachtet. Das Spektrum umfaßt:

1. Relativ warme Interglaziale mit einem breiten Ausstrich atlantischer Oberflächenwassermassen, einem hohen Karbonatfluß aus dem Pelagial, der hohe Gehalte an subpolarem Plankton und hohe Gehalte an Coccolithen aufweist (Stadien (15), 13, 11, 5.5.1, 5.1 , 1). Skandinavien war in diesen Phasen nicht vereist.

2. Temperierte Interglaziale mit einem vergleichsweise schmalen Ausstrich atlantischer Oberflächenwassermassen, einem mittleren bis hohen Karbonatfluß, der überwiegend von Planktonforaminiferenkarbonat mit

niedrigen Gehalten subpolarer Faunen aufgebaut wird und im Feinkarbonat eine klare Dominanz des kühl- temperierten Coccolithen *C. pelagicus* zeigt (Isotopenereignisse 9.3, 7.5, 7.3- 7.1, 5.4, 5.3). In Skandinavien existierten Inlandvereisungen, deren Apophysen sich bis Region der heutigen Fjorde erstreckten, jedoch nicht bis auf den Schelf reichten.

3. Ausgeprägte Kältephasen während der Interglaziale mit einem deutlichen Rückgang der Karbonatgehalte, einem erhöhten Eintrag an terrigener Grob- und Feinfraktion und einem aus der Karbonatverteilung abgeleiteten sehr schmalen Ausstrich atlantischer Wassermassen in der südöstlichen Norwegensee (Isotopenereignisse 7.4, 5.2). In diesen Phasen war Skandinavien von einer Eiskappe überzogen, deren Ausläufer die Innenschelfregion erreichten.

4. Einen schwachen Einstrom kühl- temperierter Oberflächenwassermassen aus dem Atlantik während kurzer Zeitabschnitte in den Glazialzeiten mit einer hohen Karbonatproduktion aber niedrigen Gehalten von subpolaren Elementen (Isotopenereignisse 8.6 - 8.5, 6.5 und 3.1) sowie starker Eisbergdrift im schelfnahen Sektor vor Skandinavien.

5. Eine über lange Zeitabschnitte gute Karbonaterhaltung in Glazialen und Interglazialen sowie kurzfristige Lösungsereignisse, die mit ozeanographischen Veränderungen während der Diamiktsedimentation in ursächlichem Zusammenhang stehen und kurzfristige Einbrüche in der Tiefenwasserzirkulation markieren.

6. Glazialzeiten mit besonders hohem IRD Eintrag und weiter Verbreitung der Diamikte (Stadien 6, 10, 12, 14) sowie einem Vorschub der kontinentalen Eismassen auf breiter Front bis nahe an die Schelfkante.

7. Glazialzeiten mit geringem IRD Eintrag und mittleren bis hohen Karbonatfluß, der u.a. auch signifikante Gehalte an Pteropoden aufweist (Stadium 4, glgtl. im Stadium 8) als Hinweis für eine besonders intensive Tiefenwasserzirkulation.

DRAFT, subm. to Pal., Pal., Pal.

Evolution of the Norwegian Current and the Scandinavian Ice Sheets during the past 2.6 My : Evidence from ODP Leg 104 biogenic carbonate and terrigenous records

R. HENRICH & K.-H. BAUMANN

GEOMAR, Research Center for Marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 14, Germany.

CONTENTS

INTRODUCTION

METHODS

- Determination of bulk carbonate contents.
- SEM studies of carbonate preservation patterns.
- Quantitative coccolith analysis.
- Coarse fraction analysis.

RESULTS

- Stratigraphy and determination of age models.
- Bulk carbonate records and patterns of carbonate preservation during the past 2.6 My.
- Variability of coccolith abundances and species distribution during the past 1.0 My.
- Patterns of pelagic/benthic coupling in the Norwegian Sea during the past 1.0 My.
- Terrigenous records and ice rafting of reworked nannofossils during the past 2.6 My.

DISCUSSION

- Reconstruction of surface water regimes and ice drift patterns during the past 2.6 My.
- Deep water properties in the Norwegian Sea during the past 2.6 My.
- Factors of external and internal forcing in Northern Hemisphere climate evolution during the past 2.6 My.

CONCLUSIONS

ABSTRACT

Records of biogenic and terrigenous components have been obtained from the interval corresponding to the last 2.6 Mys of ODP Sites 643 and 644 in order to reconstruct surface and deep water regimes in the Norwegian Sea.

Surface water regimes record long lasting moderate glacial conditions during the interval 2.6 Ma to 1.0 Ma. Small intrusions of Atlantic water episodically penetrated into the Norwegian Sea forming a narrow tongue along the eastern margin, which is documented at Site 644. The polar front was most probably situated between the Site 644 and 643 locations on the outer Vøring Plateau during these time intervals. Deep water regimes reflect long-term persistent corrosive bottom waters, most probably due to a weakly undersaturated water column and a low rate of carbonate shell production in surface waters. Deep water production in the Norwegian-Greenland Sea may have operated in a different way, e.g. brine formation during winter sea ice growth. Bottom waters were oxygenated throughout the entire period, and deep water was exchanged persistently with the North Atlantic.

Increased glacial/interglacial environmental contrasts are documented, reflecting a strengthening of the Norwegian Current and intensified glaciations on the surrounding land masses during the interval 1.0 Ma to 0.6 Ma. During this time a major shift in the mode of deep water production occurred.

The onset of large amplitudes in glacial/interglacial environmental conditions with maximum contrasts in surface water regimes, different modes of deep water production, and exchange rates with the North Atlantic marks the last 0.6 Ma. A broad development of the Norwegian Current is observed during peak interglacials, while during glacials seasonally variable sea ice cover and iceberg drift dominate surface water conditions.

INTRODUCTION

A major element in the evolution of Cenozoic environments has been the transformation from warm Eocene to Lower Miocene oceans into the later type of oceans characterized by strong thermal gradients, oceanic fronts, cold deep oceans and cold high latitude surface water masses (Thiede et al. 1989, Bohrmann et al. 1990, Jansen et al. 1990, Mudie et al. 1990). This transformation is linked with the climatic transition into cold high latitude climates and the surface-water connection between higher and lower latitude oceans. A major threshold of the climate system was passed with the inception of glaciers and ice-sheets in the Northern Hemisphere. The best location to monitor the onset of glaciations in the Northern Hemisphere would be in the high northern and western Arctic. So far, ODP has not yet

*to be submitted to
Marine Geology*

Surface Water Regimes and Glaciomarine Processes in the Norwegian - Greenland Sea: 450 ka to Present

Rüdiger Henrich (Kiel), Ida Beyer (Bergen) & Eystein Jansen (Bergen)

Contents

1. Introduction

- 1.1. Purpose of study and previous work
- 1.2. Oceanography
- 1.3. Pelagic and glaciomarine sedimentation processes: overview of modern environmental conditions
- 1.4. Deep sea sedimentary facies analysis: a new tool in polar marine research

2 Methods

- 2.1. Oxygen and carbon isotope stratigraphy and determination of age models
- 2.2. Analytical methods in deep sea facies analysis
- 2.3. Micropaleontological methods

3 Results

- 3.1. Sedimentological tracers and facies patterns of modern surface water masses
- 3.2. Sedimentological tracers and facies patterns of glacial deposits
- 3.3. Facies transects across the central sector of the Norwegian- Greenland Sea covering the past 450 ka
- 3.4. Glacial/interglacial variability of carbonate fluxes and preservation in the pelagic realm
- 3.5. Glacial/interglacial variability of terrigenous and organic carbon fluxes and dispersal of specific IRD tracers
- 3.6. Distribution patterns of subpolar planktic foraminifers during the past 450 ky
- 3.7. Isotopic gradients and correlated facies shifts

4 Discussion

- 4.1. Reconstruction of surface water regimes and ice drift patterns
- 4.2. Models on deep water formation in the Norwegian- Greenland Sea during glacials and interglacials
- 4.3. Correlation of marine and land paleoclimate records in the surroundings of the Nordic Seas

Conclusions

Discussion

134

Sedimentary facies of glacial–interglacial cycles in the Norwegian Sea during the last 350 ka — reply

Rüdiger Henrich and Jörn Thiede

GEOMAR, Forschungszentrum für Marine Geowissenschaften, Geb. 4, Wischhofstrasse 1–3, D-2300 Kiel 14, F.R.G.

(Received April 10, 1990; accepted June 19, 1990)

The comment by Thomson on our paper presents an alternative model for the early diagenesis of the dark diamictos which are intercalated in glacial sediments over wide areas of the Norwegian–Greenland Sea. The principle difference in the approach of Thomson and our model is that Thomson deduces the early reactions to variations in flux rates and quality of organic matter without changes in bottom-water oxygen levels. We will argue instead that early diagenetic processes have been triggered essentially by changing bottom-water properties.

Thomson's diagenetic model for metal relocations in sediment sections with dark diamictos provides a more detailed and elaborate view of the successive diagenetic environments that we only briefly discussed in our paper (Mar. Geol., 86: 312–313, fig. 17). In fact downward movement of a secondary oxidation front into the dark diamictos is responsible for the observed metal concentration profiles within and on top of the diamictos. For comparison, see the discussion on oxidation front migration into turbidites by Buckley and Cranston (1988). Also, these diagenetic reactions clearly are not contemporaneous with deposition of the diamictos. They occur with a time lag of less than 1 ky to 3 ky as suggested by oxic sediment-filled burrows truncating the diagenetic iron laminations concentrated at the redox boundary. In conclusion, there is no discrepancy between Thomson's and our views on the succession of diagenetic processes that caused the observed metal relocation profiles, but we do gratefully acknowledge Thomson's more detailed discussion on these aspects.

Two principally different mechanisms triggering the diagenetic reactions have been presented by Thomson and us. Indeed, the major open question is whether the diagenetic observations can only be

explained by changes in flux rates and quality of organic matter (e.g. Thomson's alternative model), or whether these shifts have been essentially triggered and accelerated by changing bottom-water properties (our model). In order to approach this difficult problem, we will first summarize other circumstantial evidence for changing bottom-water conditions during glacial and interglacials in the Norwegian–Greenland Sea, and then attempt to evaluate our model in more detail.

Glacial sediments in the Norwegian–Greenland Sea generally reveal a low diversity of benthic organisms, and *Cibicides wuellerstorfi*, a typical epibenthic foraminifer adapted to full oxygenated bottom-water conditions (Zahn et al., 1986; Lutze and Thiel, 1989), does not occur in glacial sediments. Also, there is a strong glacial/interglacial contrast in bioturbation features and intensity with a much richer and denser ichnofacies in the interglacial sediments. Despite the possibility that some of the shallow endobenthic foraminifera might have been adapted to low-oxygen conditions, the sporadic occurrence of sponge spicules in glacial sediments from submarine ridges demonstrate that oxygenated bottom waters were present. This is further supported by SEM dissolution studies indicating overall good carbonate preservation during "normal glacial" conditions. In conclusion, we assume that during long glacial periods bottom waters still were oxygenated, but that the bottom-water exchange and overall oxygen content was lower than during interglacials. This is further demonstrated by regional differences in glacial $\delta^{13}\text{C}$ values in benthic foraminifera in the Norwegian–Greenland Sea and North Atlantic, with more negative values in the Norwegian Sea (Jansen et al., 1989). The rapidly deposited diamictos are bereft of benthic organisms and reveal only very low

contents of highly corroded planktonic foraminifera. At this point, one may either attribute the absence of benthic organisms to the high deposition rate or invoke changes in bottom-water properties (e.g. a lower exchange rate of bottom waters due to a more stratified water column). This question can only be answered if a distinction can be made regarding whether carbonate dissolution is a bottom-water or a pore-water controlled process or a combination of both. Thomson's model explains the observed dissolution phenomena only by increased CO_2 in pore-waters derived from degradation of terrigenous organic matter under oxic conditions. Support for this assumption is the observed decrease in total organic contents in the diagenetically altered top sections of the diamictos. Since dissolution features on planktonic foraminifera were not only observed in the diagenetically altered sections but also in the deeper, unchanged, dark grey parts of the diamictos, we have assumed that at least part of the dissolution took place at the sea floor. Nevertheless, the possibility of additional dissolution under early diagenetic conditions, as discussed by Thomson, is strongly evident from the shift in the total organic carbon records in the topmost diamicton sections. Also, such early diagenetic carbonate dissolution processes could contribute CO_2 to the bottom water masses and thus enhance seafloor dissolution processes (compare the discussion in Cranston and Buckley, 1990).

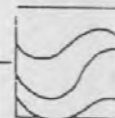
Hitherto we have not been able to discover any difference in the quality of organic carbon within the diamictos and the surrounding glacial sediments. A prevalence of terrigenous organic matter is indicated by preliminary Rock EVAL data. During microscopic analysis abundant coal fragments have been detected in some diamictos (Bischof et al., in press; Henrich, 1990). However, because Rock EVAL pyrolysis is only a first and rough approach to characterizing the organic carbon in young sediments, we have started a more detailed geochemical analytical programme for more accurately characterizing the shifts in terrigenous versus marine organic carbon content in glacial/interglacial sediments. Results are not yet available, but they will contribute essential additional aspects on the relative proportion of seafloor dissolution processes.

A major precondition in Thomson's alternative model excluding bottom-water changes is the very rapid deposition rate of the diamictos. This is obviously the case for the diamicton occurrences discussed in our paper (Mar. Geol., 86: 283–319). Additional work on long-term shifts in glacial/interglacial sedimentation patterns in the Norwegian Sea carried out on the ODP Leg 104 cores indicates that similar diamictos are intercalated in sediments that have been deposited at an overall very low sedimentation rate (e.g. less than 1–2 cm/ky; Henrich, 1989). Facies with dark diamictos occur repeatedly throughout the entire glacial/interglacial section of the past 2.57 Ma, but from 2.57 Ma to 1.2 Ma interglacial deposits are restricted to a few and less-pronounced occurrences at Site 644 which is situated close to the shelf edge. Strong persistent facies-independent carbonate dissolution is recorded throughout the sections from 2.57 Ma to about 1.2 Ma followed by a long transitional period with a gradual decrease in dissolution from 1.2 Ma to about 0.6 Ma (Henrich, 1989). The planktonic oxygen isotope records of the section from 2.57 Ma to 1.2 Ma reflect strongly depleted $\delta^{18}\text{O}$ values compared to the Atlantic records, while the benthic records in the Norwegian Sea and the North Atlantic are similar (Jansen et al., 1988, 1989). The light planktonic oxygen isotope values and the large deep water to surface water oxygen isotopic gradient has been attributed to an overall reduced surface-water salinity in the Norwegian Sea. Under such conditions the mode of formation of dark diamictos may have operated at much lower deposition rates because the more general stabilization of the water column may have reduced bottom-water exchange resulting in more persistent dissolution over longer periods.

In conclusion, we infer that early diagenetic reactions in Norwegian Sea deep-sea sediments were triggered by shifts in bottom-water properties with episodic short-term dissolution pulses in the more recent palaeoclimatic interval (e.g. the last 600 ky) and more persistent dissolution during the earlier period (2.57–1.2 Ma). Finally, we wish to acknowledge once more the very interesting comment by Thomson that provides additional aspects on the early diagenetic processes. He has provided us with the opportunity of evaluating our palaeo-oceanographic model in more detail.

References

- Bischof, J., Koch, J., Kubisch, M., Spielhagen, R. and Thiede, J., in press. Nordic Seas surface ice drift reconstructions — evidence from ice rafted coal fragments during oxygen isotope stage 6. In: J.A. Dowdeswell and J.D. Scourse (Editors), *Glaciomarine Environments: Processes and Sediments*. Geol. Soc. London Spec. Publ.
- Buckley, D.E. and Cranston, R.E., 1988. Early diagenesis in deep sea turbidites: the imprint of paleo-oxidation zones. *Geochim. Cosmochim. Acta*, 52: 2925–2939.
- Cranston, R.E. and Buckley, D.E., 1990. Redox reactions and carbonate preservation in deep-sea sediments. *Mar. Geol.*, 94: 1–8.
- Henrich, R., 1989. Glacial-interglacial cycles in the Norwegian Sea: Sedimentology, paleoceanography and evolution of Late Pliocene to Quaternary Northern Hemisphere climate. In: O. Eldholm, J. Thiede et al. *Proc. Ocean Drill. Program, Sci. Results*, 104: 189–217.
- Henrich, R., 1990. Cycles, rhythms, and events in Quaternary Arctic and Antarctic glaciomarine deposits. In: U. Bleil and J. Thiede (Editors), *Geological History of the Polar Oceans: Arctic Versus Antarctic*. (NATO ASI Series C.) Kluwer, Dordrecht, The Netherlands, pp.213–244.
- Jansen, E., Bleil, U., Henrich, R., Kringstad, L. and Slettemark, B., 1988. Paleoenvironmental changes in the Norwegian Sea and the Northeast Atlantic during the last 2.8 Ma: ODP/DSDP Sites 610, 642, 643 and 644. *Paleoceanography*, 3(5): 563–581.
- Jansen, E., Slettemark, B., Bleil, U., Henrich, R., Kringstad, L. and Røfsen, S., 1989. Oxygen and carbon isotope stratigraphy and magnetostratigraphy of the last 2.8 Ma: Paleoclimatic comparisons between the Norwegian Sea and the North Atlantic. In: O. Eldholm, J. Thiede et al. *Proc. Ocean Drill. Program, Sci. Results*, 104: 255–272.
- Lutze, G.F. and Thiel, H., 1989. *Cibicides wuellerstorfi* and *Planulina ariminensis*, elevated epibenthic foraminifera. *Ber. Sonderforschungsbereich 313*, Univ. Kiel, 6, pp.31–46.
- Zahn, R., Winn, K. and Sarnthein, J., 1986. Benthic $\delta^{13}\text{C}$ and accumulation rates of organic carbon: *Uvigerina peregrina* and *Cibicides wuellerstorfi*. *Paleoceanography*, 1(1): 27–42.



Sedimentological and biological differences across a deep-sea ridge exposed to advection and accumulation of fine-grained particles

Sedimentology
Benthic ecology
Deep-sea ridge
Vøring Plateau
Norwegian Sea

Sédimentologie
Écologie benthique
Dorsale profonde
Plateau de Vøring
Mer de Norvège

Preben JENSEN ^a, Jan RUMOHR ^b and Gerhard GRAF ^b

^a Marine Biological Laboratory, University of Copenhagen, Strandpromenaden 5, DK-3000 Helsingør, Denmark.

^b Geomar Research Center for Marine Geosciences, University of Kiel, Wischhofstrasse 13, Kiel 14, FRG.

Received 7/02/91, in revised form 30/03/92, accepted 2/04/92.

ABSTRACT

Large amounts of clay and silt particles from the northern Vøring Plateau (Norwegian Sea) accumulate on a ridge (Vøring Plateau escarpment) situated at 1 245-1 310 m depth on the northern Vøring Plateau. Calculated Holocene sedimentation rates are up to 18 cm ky⁻¹, while amounting to less than 1 cm ky⁻¹ on the slope south of the ridge. Six stations were sampled - three on each side of the ridge - to obtain quantitative information of different biological components and relate these observations to the environmental conditions. Pronounced biological differences between the southern and northern sites are evident in terms of oxygen consumption, meio- and macrofauna composition, meiofauna biomass and meiofauna depth distribution. A specific fauna consisting of pogonophorans and nematode assemblages of relatively large-sized animals inhabits areas on Vøring Plateau which are characterized by high sedimentation rates and high organic carbon content. Accumulation of particles larger than 63 µm in sediment horizons between 6-10 cm depth is possibly due to vertical particle transports by a burrowing enteropneust.

Oceanologica Acta, 1992. 15, 3, 287-296.

RÉSUMÉ

Différences sédimentologiques et biologiques d'un côté à l'autre d'une dorsale profonde exposée à l'advection et à l'accumulation de fines particules

D'importantes quantités de particules argileuses et de vase en provenance du plateau continental de la Mer de Norvège se sont accumulées sur une dorsale, l'escarpement du plateau Vøring, à 1 245-1 310 m de profondeur. Les taux de sédimentation calculés pour l'Holocène y atteignent 18 cm par millénaire alors que, plus au sud, sur le talus continental, ils sont inférieurs à 1 cm par millénaire. Six stations ont été échantillonnées (trois de chaque côté de la dorsale) afin de quantifier les constituants biologiques et de comparer ces observations aux caractéristiques de l'environnement. Des différences notables entre les stations du nord et celles du sud sont observées dans la consommation de l'oxygène, dans la composition de la macrofaune et dans la composition, la biomasse et la répartition verticale de la méiofaune. Des populations de pogonophores et de nématodes, constituées d'ani-

Der aktive mittelozeanische Rücken als Sedimentationsraum —
Zusammensetzung und Dynamik der Sedimente
am Kolbeinsey-Rücken (N^o Island)

An active mid-ocean ridge as sedimentary environment —
Sediment composition and dynamics at Kolbeinsey Ridge (N^o Iceland)

Von KLAS SVEN LACKSCHEWITZ, REINHARD OEHMIG und
HANS-JOACHIM WALLRABE-ADAMS, Kiel

Mit 6 Abbildungen und 1 Tabelle im Text

LACKSCHEWITZ, K. S., OEHMIG, R. & WALLRABE-ADAMS, H.-J. (1991):
Der aktive mittelozeanische Rücken als Sedimentationsraum - Zusammen-
setzung und Dynamik der Sedimente am Kolbeinsey-Rücken (N^o Island).
[An active mid-ocean ridge as sedimentary environment - Sediment com-
position and dynamics at Kolbeinsey Ridge (N^o Iceland).] - Zbl. Geol.
Paläont. Teil I, 1990 (11): 1727-1738; Stuttgart.

Abstract: Sedimentation on mid-ocean ridge north of Iceland (Kolbeinsey Ridge) is controlled by several factors. Volcanism is important for the active ridge segment by supplying much of its sediments. Currents and other processes affect deposition in the morphologically extreme region of transform disturbances, resulting in a wide spectrum of possible sedimentary facies.

Analyses of coarse fractions and settling velocities proved to be valuable tools in attempts to define highly variable sedimentary environments of the ridge in terms of responsible transport and depositional processes.

Zusammenfassung: Die Sedimentation am mittelozeanischen Rücken nördlich von Island (Kolbeinsey-Rücken) wird von mehreren Faktoren beeinflusst. Hervorzuheben ist der vulkanogene Eintrag im aktiven Rückensegment, der einen bedeutenden Anteil der Sedimentkomponenten liefert. Die Überprägung der Ablagerungen durch Strömungen und zusätzliche Sedimentationsprozesse in morphologisch extremen Bereichen (Transform-Störungen) erweitern das Spektrum möglicher Sedimentfaziestypen.

Grobfraktions- und Sinkgeschwindigkeitsanalysen erwiesen sich als geeignete Methoden, um die engräumig wechselnden Sedimentationszonen im Rückenbereich den jeweils wirksamen Ablagerungs- und Transportprozessen zuzuordnen.

PLANKTON AND TEPHRA EVENTS ON THE CONTINENTAL MARGIN OFF MID-NORWAY DURING TERMINATION I

Sigurd Locker and Frank Blaume
Sonderforschungsbereich 313, Universität Kiel

Helmut Erlenkeuser
Institut für Reine und Angewandte Kernphysik, Universität Kiel

Jan Rumohr
GEOMAR, Forschungszentrum für Marine Geowissenschaften, Kiel

ABSTRACT

A high accumulation area on the continental slope west of Gamlembanken (67°N-08°E, 1000 m of water depth) provided a composite section comprising >900 cm of postglacial sediments, which were studied for calcareous and siliceous plankton, and tephra particles.

The first appearance of coccolithophorids, diatoms and radiolarians indicates that northern Atlantic surface waters entered the area off mid-Norway near 13,300 ¹⁴C YBP, thus establishing a weak precursor of the Norwegian Atlantic Current along the shelf edge. According to plankton data, this precursor current persisted throughout Boelling/Alleroed times and also the Younger Dryas, when the Vedde ash settled in the area at 10,600 ¹⁴C YBP. Due to an increased nutrient supply to surface waters, diatoms developed a strong acme at 10,250 ¹⁴C YBP. Coccolithophorids and radiolarians attained higher frequencies only subsequent to ice rafting after 9,650 ¹⁴C YBP, which presumably corresponds to the full establishment of the Norwegian Atlantic Current off mid-Norway. The maximum of radiolarians, amounting to 13,400 skeletons/gram sediment, appeared only after Atlantic time at about 3,800 ¹⁴C YBP.

INTRODUCTION

During the last years several depositional sites have been detected along the Norwegian to Spitsbergen continental margin which provided high resolution records of late Pleistocene to Holocene paleoceanographic events. The sediments recovered have been studied on sediment properties, oxygen and carbon isotopes, and various protistan groups (Bjoerklund, Thiede and Hortedahl, 1979; Jansen et al., 1983; Jansen and Bjoerklund, 1985; Rokoengen et al., 1991; Weinelt et al., 1991; Koc Karpuz and Jansen, 1992; Sarnthein et al., 1992), which contributed to decipher important aspects of the deglaciation history of the Norwegian-Greenland Sea.

One of the most comprehensive sediment sequences has been obtained from the high accumulation area of Gamlembanken, located on the continental slope off mid Norway (Figure 1). The area has been mapped in detail by 3.5 kHz subbottom profiling and sediment sampling (Blaume, 1990, 1992; Rumohr, 1990a, subm.). This paper presents the results of sedimentological and paleontological investigations performed on cores GIK 23312-1/2 and GIK 23331-1/2 from the highaccumulation area. Both cores

Comparing sieve and sedimentation balance analysis of beach, lake and eolian sediments using log-hyperbolic parameters

Lars Chresten Lund-Hansen^a and Reinhard Oehmig^b

^a*Institute of Geology, Marine Geological Department, Aarhus University, Ny Munkegade Bygn. 520, DK-8000 Århus, Denmark*

^b*GEOMAR Research Center for Marine Geosciences, Wischofstraße 1–4, D-2300 Kiel, Germany*

(Received June 21, 1991; revision accepted February 17, 1992)

ABSTRACT

Lund-Hansen, L.C. and Oehmig, R., 1992. Comparing sieve and sedimentation balance analysis of beach, lake and eolian sediments using log-hyperbolic parameters. *Mar. Geol.*, 107: 139–147.

Sieving and settling analyses of 29 samples from different sedimentary environments have been compared with the use of invariant log-hyperbolic parameters. Settling velocities were not converted into millimetre size. The comparison was based on kurtosis, skewness and sorting of the distributions. The comparison of the parameter values have been evaluated by a two-tailed *t*-test. The log-hyperbolic parameters values for kurtosis between the two methods differed significantly for the beach sediments. Skewness differed significantly in all three environments and sorting only differed significantly for the beach sediments. ($q-N$) a measure of fit between observations and the estimated log-hyperbolic distribution differed significantly in the beach and eolian sediments. The study shows that settling velocities give a better fit to the log-hyperbolic distribution opposed to sieve analysis. The study shows that the differences in the log-hyperbolic sediment parameter values differ significantly in nearly half of the comparisons. It is concluded, that great attention must be paid to the method of grain-size analysis.

SETTLING-VELOCITY OF SAND-SIZE FRACTION FOR COMPARISON OF QUATERNARY GLACIAL/INTERGLACIAL SEDIMENTS FROM NORTHERN NORTH ATLANTIC

K. Michels (Special Research Projekt 313, Christian-Albrechts-University Kiel, Olshausenstr. 40, D - 2300 Kiel, Germany)

Depositional environment varies significantly due to changes of the oceanographic circulation pattern during glacial/interglacial cycles in quaternary times. Glacial times are generally characterized by high amounts of terrigenous detritus whereas interglacial maxima are mainly made up of biogenic particles with foraminiferal shells as main constituent.

Based on the determination of the settling velocity in a 'Settling Tube' it is possible to define specific hydrodynamical properties. The settling velocity is influenced by size, density, shape and surface roughness of the particles.

The result of a settling-tube-analysis is a settling-velocity-distribution with several peaks representing the modes of different particle-assemblages.

A next step is to characterize the sediment particles of the various peaks. This is done by means of a 'Separator', where particles can be distinguished depending on their sinking rate (e.g. different species of foraminifers).

Finally, the peaks are expressed in percentage of the total settling-velocity-distribution.

These results will be presented for samples from different core sites in the northern North Atlantic for oxygen isotope stages 1, 2, 5 and 6.

Abstract: Fourth International Conference on Paleoceanography
Abstracts, 21.-25. September 1992, S.198, Kiel

in Druck bei:

SEDIMENTOLOGY

Journal of the International Association of Sedimentologists

Entrainment of Planktonic Foraminifera:

Effect of Bulk Density

REINHARD OEHMIG

GEOMAR, Research Center for Marine Geosciences

2300 Kiel 14 (Germany), Wischhofstraße 1-3

ABSTRACT

Depositional hydrodynamics have been studied by the use of settling rate distributions of Norwegian deep-sea sediments (between Jan Mayen Island and Vøring Plateau), together with Shields' critical shear-stress velocities. Planktonic foraminifera are the dominant sand component of these sediments. The bulk density of the foraminifera was calculated from their settling velocity, sieve-size and shape, using the equations and sedimentation instruments of Brezina (1979, 1989). Density decreases from 2.39 g/cm^3 at 0.05 mm diameter to 1.37 g/cm^3 at 0.35 mm diameter. These density and size data were used for construction of a threshold sediment movement curve (Shields, 1936). The two components, the sand-sized foraminifera and the quartz and carbonate silt, seem to be transport equivalent due to the similarity in their Shields' critical shear-stress velocities and due to the observed correlation of foraminifera size with decreasing percentage of fine fraction.

HYDRODYNAMIC PROPERTIES AND GRAIN-SIZE CHARACTERISTICS OF VOLCANICLASTIC DEPOSITS ON THE MID-ATLANTIC RIDGE NORTH OF ICELAND (KOLBEINSEY RIDGE)¹

REINHARD OEHMIG AND HANS-JOACHIM WALLRABE-ADAMS

GEOMAR Research Center for Marine Geosciences

Wischhofstr. 1-3, W-2300 Kiel 14

Germany

ABSTRACT: Surface sediments from a transect across the mid-ocean ridge north of Iceland (Kolbeinsey Ridge) have been analyzed according to their compositional, textural and hydromechanical characteristics. The results were used to reconstruct sediment formation and depositional processes.

The ridge sediments are dominated by volcanoclastic particles of hyaloclastic and pyroclastic origin. These particles show a wide variety in size, shape and density. Single-grain settling velocities of the different glass types reveal the suitability of this parameter as a reflector of the particle properties of size, shape and density, which are also known to be relevant to grain transport.

Observations concerning different current expositions of central ridge sediments, combined with the parameters of settling velocity distribution, grain-size distribution and sediment particle composition, were applied to distinguish between transport association with rare, easily movable glass shards and poorly sorted sediments in sheltered ponds. A bimodal settling velocity distribution of steep ridge-flank sediments probably indicates the effect of sediment admixture from poorly sorted mass flows. Alternating coarse- and fine-grained layers characterize the transition between ridge-glass sands and the ridge-adjacent plain, which is dominated by slow-settling pelagic material.

TERRA

abstracts

Volume 1, Number 1, March 1989

European Union of Geosciences EUG V 27

SY04-25P

ADVECTION AND ACCUMULATION OF PELAGIC MATERIAL ON A RIDGE, NORTHERN VOERING PLATEAU ESCARPMENT

J. RUMOHR.
(University of Kiel, Kiel, FRG).

Mapping of an area 35 x 70 km along the Voering Plateau escarpment with a high resolution sub-bottom profiling system (3,5 kHz) revealed regional morphology controlled differences in sediment thickness especially of layers deposited during interglacial times (e.g. the Holocene). The thickness of a layer may differ from one to the other place by a factor of more than 10.

Sediment cores on a cross profile can be correlated by a typical Holocene to late Glacial sequence of relative downcore changes of the following parameters: $\delta^{18}O$, $\delta^{13}C$, Ca-carbonate, C and grain-size distribution. The regional changes of some parameters can be interpreted in correlation with the accumulation rates: C- and clay content are highest in the center of an area of maximum accumulation some kilometers north from the top of the submarine ridge. Sand (foram) contents vary between 1.5 % in the sedimentation center and 16 % on the slope.

Long term bottom current measurements are in good agreement with the idea of a morphology controlled anticyclonic vortex (Taylor column) in the area of investigation. This could serve for an explanation of relatively high bottom current velocities on the southern slope with little deposition of fine material and a zone of maximum accumulation for Holocene sedimentation north of the top of the ridge. Deeper layers show different regional sediment thicknesses due to changes in bottom current directions during geological times.

Biological implications and a regional pattern of benthic structures will be discussed in terms of food supply, substrates and other physical conditions.

SY04-10

HIGH ACCUMULATION AREAS ON THE CONTINENTAL SLOPE OFF NORTHERN NORWAY AND THE CONCEPTION OF WINTER WATER CASCADES

J. RUMOHR*, and F. BLAUME.
(University of Kiel, Kiel, FRG).

Along the Norwegian continental slope between 65° and 75° N local high accumulation areas can be traced in water depths below 800 m with a tendency towards greater depths to the north.

An area of extreme Holocene sediment thickness (up to 7 m) and a pre-Holocene unit (up to 10 m) with the center of sediment thickness in the same place on the Norwegian continental slope (67° N) was mapped by means of 3.5 kHz sub-bottom profiling in water depths of 700 - 1,200 m. The regional distribution of sediment parameters including stratigraphic and absolute ages ($\delta^{18}O$, $\delta^{13}C$, ^{14}C) in the area of high accumulation - some 25 km in diameter - are described. Several morphology controlled oceanographic processes possibly involved in downslope sediment transport are discussed. Among these, downslope cascades of winter water formed on banks near the shelf break seem to be the most important process causing the local concentration of advected fine sediments.

The source areas are covered by icerafted pebbles and coarse sand from the last deglaciation period and therefore protected against deep erosion. So the Holocene sediment transport mainly affected "fresh" sedimented material. Further downslope in the area of high accumulation the corresponding Holocene/pre-Holocene sedimentary record provides information with high resolution about the oceanographic regime near the shelf break.

Similar local sediment accumulations were found along the continental slope up to west of Bear Island (75° N, 14° W). Here in water depths of 1,800 m a sequence of late Pleistocene/Holocene age with a high Holocene accumulation rate possibly reflects oceanographic processes comparable to those which generated the high accumulation units on the continental slope at 67° N. The physical sediment properties of these units will be compared and discussed.

These high local sediment accumulations could probably provide sedimentological documents for the contribution of deep water formed on shelves.

Revised manuscript
Deep Sea Res.

A HIGH ACCUMULATION AREA ON THE CONTINENTAL SLOPE OFF NORTHERN NORWAY AND SEDIMENT TRANSPORT FROM THE OUTER SHELF BY CASCADING WINTER WATER x

by

Jan Rumohr

GEOMAR, Forschungszentrum für Marine Geowissenschaften an der Universität,
Kiel Wischhofstraße 1-3, D 2300 Kiel, W-Germany.

Abstract

An area of extreme Holocene sediment thickness (up to 7 m) and a late Weichselian unit was mapped in water depths of 700 - 1,200 m on the Norwegian continental slope (67° N) by means of 3.5 kHz subbottom profiling. The regional distribution of sediment parameters and accumulation rates in the area of accumulation - some 30 km in diameter - are described, and some morphology - controlled oceanographic processes possibly involved in downslope sediment transport are discussed. Among them, cascading winter water formed on banks near the shelf break seems to be the most effective sediment transport process.

The source areas on the shelf and the upper continental slope are protected against deep erosion by a lag of ice-rafted pebbles and coarse sand deposited during the last deglaciation. Thus the Holocene sediment transport mainly affected freshly sedimented and biologically resuspended material from the seabottom.

INTRODUCTION

The ocean surface currents of the Norwegian Sea are dominated by the inflow of warm Atlantic water (Norwegian Current). A frontal system, that generally follows the shelf break separates this current from colder and less saline water masses of the northward drifting Norwegian Coastal Current (JOHANNESSEN 1986).

The sea floor of the Norwegian outer continental shelf and the upper slope is characterized by areas of surficial erosion and reduced Holocene sedimentation. Large areas are covered by lag sediments and ice rafted gravels deposited during the last deglaciation (HOLTEDAHL 1981, VORREN et al. 1983). On the inner shelf and inner parts of transversal troughs on the shelf as well as in deeper regions of the continental slope, the late Pleistocene to Holocene sediment column is more complete and can be interpreted in terms of paleoclimatic changes, ice retreat and the local oceanographic processes (HALD & VORREN 1987, HOLTEDAHL 1981, HOLTEDAHL & BJERKLI, 1982, VORREN et al., 1984, 1988). During the Holocene the outer shelf and upper slope was (and still is) an area of sediment export whereas the deeper continental slope accumulated the topographically controlled advected material. A regional center of deposition some 30 km in diameter and at 700-1250 m depth on the Norwegian continental slope (around 67° N; 8° E) was

Organisches Material in pelagischen Sedimenten: Glaziale/Interglaziale Variationen im Europäischen Nordmeer



Dissertation
zur Erlangung des Doktorgrades
der Mathematisch-Naturwissenschaftlichen Fakultät
der Christian-Albrechts-Universität
zu Kiel

vorgelegt von
Thomas Wagner
1993

Zusammenfassung/Abstract	1
1. Einleitung und Zielsetzung	4
2. Grundlagen	9
3. Das Europäische Nordmeer	15
3.1 Physiographie	15
3.2 Hydrographie.....	16
3.3 Paläo-Ozeanographie	19
3.4 Lithofazies-Verteilung in den Sedimenten.....	22
3.5 Organisches Material in spätpleistozänen und holozänen Sedimenten.....	25
3.6 Herkunft des organischen Materials.....	27
4. Methodik	39
4.1 Bestimmung des organischen Kohlenstoffs (TOC)	40
4.2 Bestimmung des Gesamtstickstoffs (N _{tot}).....	41
4.3 Die Rock-Eval Pyrolyse.....	42
4.4 Stabile Kohlenstoff-Isotope ($\delta^{13}\text{C}_{\text{org}}$).....	44
4.5 Organisch-petrologische Untersuchungen	45
5. Ergebnisse	52
5.1 Organische Petrologie an TOC-armen Sedimenten: Signifikanz und Limitierung der Analysemethode	52
5.2 Mineral-Matrix Effekte in unreifen feinklastischen Sedimenten.....	57
5.3 Kohlepetrologische und isopenchemische Untersuchungen an IRD > 500 μm sowie an Probenmaterial aus potentiellen Liefergebieten solcher Klasten	60
5.4 Organischer Charakter glazialer und interglazialer Sedimente des EN	69
5.5 Räumliche und zeitliche Verteilung organischer Faziesseinheiten im EN.....	89
6. Diskussion	101
6.1 Korrelation organischer und lithologischer Faziesseinheiten	101
6.2 Frühdiagenese mariner organischer Substanzen in Sedimenten des EN.....	105
6.3 TOC-reiche Klasten in glazialen und deglazialen Sedimenten - Ein paläo-ozeanographisch signifikanter Tracer?	109
6.4 Hinweise zur Entstehung TOC-reicher Diamikte während glazialer und deglazialer Klimaphasen.....	114
6.5 Paläo-ozeanographische Implikationen.....	115
7. Schlußfolgerungen	124
8. Literaturhinweise	128
Liste der verwendeten Abkürzungen	
Liste der Abbildungen, Tabellen und Phototafeln	
Appendix	
Datenanhang I - IV	

Zusammenfassung

Organisch-geochemische (TOC, Rock-Eval Pyrolyse, C/N, $\delta^{13}\text{C}_{\text{org}}$) und -petrologische Untersuchungen wurden an sieben Kernen aus dem Europäischen Nordmeer (EN), fokussiert auf die Sedimente der Sauerstoff-Isotopenstadien 6-5 und 2-1, durchgeführt. Variationen im Eintrag von autochthonem und allochthonem organischen Material (OM) im Wechsel zwischen glazialen und interglazialen Klimaphasen konnten so mit maximaler zeitlicher Auflösung erfaßt werden. Aufbauend auf diesen Grunddaten wurde ein organisches Fazieskonzept für pelagische, TOC-arme (< 1 Gew.%) Sedimente entwickelt. Anschließend wurden zeitliche und räumliche Variationen im organischen Charakter der Sedimente in Bezug zur paläo-ozeanographischen und paläo-klimatischen Entwicklung des Ablagerungsraums diskutiert. Zur Klärung potentieller Liefergebiete für TOC-führenden IRD, der verstärkt in den Sedimenten des Isotopenstadiums 6 im östlichen arktischen Raum, der Fram-Straße und dem EN auftritt, wurden geochemische (TOC, $\delta^{13}\text{C}_{\text{org}}$) sowie kohlepetrologische Untersuchungen durchgeführt.

Die Verteilung der organischen Fazies belegt, sowohl für glaziale, als auch für interglaziale Kernabschnitte, eine Dominanz von allochthonem OM. Glaziale und deglaziale Sedimente sind durch ansteigende TOC-Gehalte, die auf glaziomarinen Sedimenteintrag zurückzuführen sind, charakterisiert. Der Übergang zu interglazialen Klimaphasen ist, insbesondere in den Sedimenten der Norwegischen See, durch einen deutlichen Rückgang der TOC-Gehalte mit vorherrschend oxidiertem OM bestimmt. Autochthones OM ist nur in den Sedimenten des Isotopensubstadiums 5.5.1 auf dem äußeren Vøring-Plateau und dem südlichen Grönland-Becken, bedingt durch deutlich ansteigende Sedimentationsraten, sowie den oberflächennahen Sedimenten mit erhöhten Anteilen überliefert.

Die Abfolge organischer Faziesseinheiten mit zunehmender Kernteufe weist auf eine unterschiedliche Erhaltungsfähigkeit von autochthonem und allochthonem OM hin. Frühdiagenetische Prozesse reduzieren selektiv das autochthone OM in den obersten Dezimetern der Sedimente auf 50-60 % des an der Oberfläche abgelagerten marinen OM. Insgesamt spiegelt sich diese Tatsache auch in der unterschiedlichen Übereinstimmung organischer und lithofazieller Faziesseinheiten wider. Glaziale und deglaziale Kernabschnitte zeigen aufgrund des dominant allochthonen (abbau-resistenten) OM eine optimale zeitliche Korrelation. Im Gegensatz dazu ist die z.T. differenzierte lithofazielle Gliederung der Kernabschnitte des Isotopenstadiums 5 im TOC-Signal nicht überliefert. Hieraus können Hinweise auf eine intensive diagenetische Remineralisation des ursprünglich abgelagerten (vermutlich autochthonen, labilen) OM abgeleitet werden.

Glaziomarine Sedimentationsprozesse haben insbesondere in der Norwegischen See während glazialer und deglazialer Klimaphasen mit einem verstärkten Eintrag von allochthonem, z.T. thermisch reifem OM (Kohle- und Schwarzschiefer-Klasten) zur Ablagerung von Diamikten geführt. Die in das Beckenzentrum ausstreichenden Horizonte deuten auf TOC-reiche jurassisch-kretazische Ursprungsgesteine, die entlang der östlich angrenzenden kontinentnahen Schelfe in geringer Wassertiefe anstehen, hin. Eine exakte Eingrenzung der Liefergebiete ist jedoch aufgrund der großräumigen Vorkommen dieser Gesteine auf dem Norwegischen Schelf, der Barents-See und dem zirkum-arktischen Hinterland, sowie der sehr ähnlichen thermischen Reife und Mazeralzusammensetzung, nicht möglich. Für das Isotopensubstadium 6.3 wurde eine Rekonstruktion der Paläo-Eisdrift, basierend auf einem charakteristischem geochemischen Signal in den Sedimenten, aus dem Boreas-Becken und der Jan-Mayen-Bruchzone, das auf Ton-/Siltsteine auf Andøya als Ursprungsgesteine hinweist, durchgeführt.

Holocene sedimentation in the Skagerrak: A review

Tjerd C.E. van Weering^a, Jan Rumohr^b and Gerd Liebezeit^c

^aNIOZ, P.O. Box 59, 1790 AB Den Burg, Texel, The Netherlands

^bGeomar, Wischhofstraße 1-3, D-2300 Kiel 14, Germany

^cForschungszentrum TERRAMARE e.V., Schleusenstraße 14, D-2940 Wilhelmshaven, Germany

(Received March 11, 1993; accepted March 12, 1993)

ABSTRACT

Van Weering, T.C.E., Rumohr, J. and Liebezeit, G., 1993. Holocene sedimentation in the Skagerrak: A review. In: G. Liebezeit, T.C.E. van Weering and J. Rumohr (Editors), *Holocene Sedimentation in the Skagerrak*. *Mar. Geol.*, 111: 000-000.

Stratigraphic, sedimentological, geochemical and micropaleontological aspects of Holocene sedimentation processes in the Skagerrak are reviewed. Published data show the Skagerrak to be the main depositional basin of the North Sea with additional inputs from the North Atlantic, the Baltic and the Scandinavian mainland. As this area is a highly dynamic and complex environment it is difficult to define overall controlling factors and processes. From a consideration of available and lacking approaches and data suggestions are made for future research.

Introduction

Continental shelves and slopes are the main areas of sediment deposition in the world ocean. Berner (1982) estimates that up to 90% of particulate material produced in or imported into the sea are incorporated here into sedimentary sequences in which information on paleoenvironments are stored. Shelves and slopes are highly dynamic environments where sedimentation is controlled by sediment transport and sorting as well as chemical and biological alteration until final deposition on the shelf and continental slope below the depth of turbulent surface water mixing.

Sediment transport on the shelf is to a certain extent driven by permanent and tidal currents roughly parallel to the coast line. Occasional strong energy input due to wind stress, swell from the open ocean, heat loss and other meteorologically forced processes may, however, completely change the transport regime (e.g. Kuijpers et al., 1993a, this volume) and thereby the quality, direction and above all the amount of material transported. As a consequence sediment sequences with high accumulation rates appear to be most probably the

accumulated "normal" geological results of repeated "unnatural" short term high energy events.

Nevertheless, it is in these rapidly accumulating sediments that significant and high resolution information is stored on sediment sources and paleometeorological and paleoceanographic processes and events that controlled the deposition of sediment. Also from geochemical and micropaleontological analyses additional evidence is obtainable on past climates, a fact which is of particular importance in view of the ongoing global change discussion.

The Skagerrak is a unique feature of the North Sea (Fig. 1) combining both slope and shelf morphology. Bordered by the coasts of Denmark, Norway and Sweden, it represents the deepest part of the present North Sea basin. Water depths here are up to 700 m. Thus, the Skagerrak forms a natural topographic sediment trap receiving inputs from the entire northwest European drainage systems and the North Sea coast.

The northern slope of the Skagerrak shows an irregular topography cut into crystalline rocks of the Scandinavian basement by glacial processes



Miliolinella subrotunda (Montagu), a miliolid foraminifer building large detritic tubes for a temporary epibenthic lifestyle

Teilprojekt A3:

A.V. Altenbach, T. Heeger, F. Linka, M. Spindler and A. Thier

Senckenbergisches Institut, D-6000 Frankfurt am Main, Germany

BESIEDLUNGSMUSTER UND STOFFEINTRAG IM BENTHAL

ABSTRACT

Altenbach, A.V., Heeger, T., Linka, F., Spindler, M. and Thier, A., 1991. *Miliolinella subrotunda* (Montagu), a miliolid foraminifer building large detritic tubes for a temporary epibenthic lifestyle. In: M.A. Lange (Editor), *Foraminiferal Studies*, Elsevier, Amsterdam, 30, 293-294.

Kurzfassungen

Live observations, cytological characterization and quantitative measurements on *Miliolinella subrotunda* (Montagu, 1803) sampled from the northern and southern Atlantic Ocean are presented. *M. subrotunda* facultatively constructs a long, conical tube lifting the test several millimeters above the sediment surface. A thickened cone of base anchors the construction on the sediment surface and a long, flexible tube branches into the velocity profile of the bottom current. The elevated test is placed on top, surrounded by the uppermost part of the tube. This construction allows the organisms to feed in the particle stream above the sediment surface. In comparison to species living in and on the surface sediments, *M. subrotunda* apparently shows higher biomass values of food ingested and larger amounts of reserve substances. Changes in shape and structure that adjust drag on the tubes include a broadened apical base, a flexible tube, and a rounded top. From histological measurements it is concluded that the tubes are constructed over a short period of their lifetime.

Introduction

Benthic foraminifera utilize a variety of adaptations to access water levels with faster currents, such as settling on stones, algae or macrofaunal burrows protruding from the sediment surface into the water column. Several agglutinated foraminifera show test constructions raised from the sediment (Lipps, 1983; Altenbach et al., 1988) and one miliolid is known to use sponge spicules to extend the range of potential for activities (Lutze and Altenbach, 1988). In the case of miliolids, the production of detrital coverings the test and part of the surrounding area is well de-

scribed (Röhrlich, 1936). In the present case we focus on a special type of organic, tubiform crust on which the test is elevated off the sediment surface.

Material and methods

During cruises *Meteor* 7, *Polarstern* Ark III/3 and *Rosendin* 141 multicorer and grab samples were taken in the northern and southern Atlantic Ocean for studies of deep-sea benthic foraminifera (Table 1). At these locations, visual and microscopic observations of the sediments revealed benthic foraminifera on top of agglutinated tubes extending up from the sediment surface. Live organisms were recovered with needle tweezers from the sediment, covered in seawater, examined under a binocular microscope and preserved for sub-

Correspondence to: A.V. Altenbach, Senckenbergisches Institut, D-6000 Frankfurt am Main, Germany.

Miliolinella subrotunda (Montagu), a miliolid foraminifer building large detritic tubes for a temporary epibenthic lifestyle

A.V. Altenbach, T. Heeger, P. Linke, M. Spindler and A. Thies

Sonderforschungsbereich 313, Universität Kiel, Olshausenstraße 40, 2300 Kiel, Germany

(Received March 21, 1992; revision accepted August 1, 1992)

ABSTRACT

Altenbach, A.V., Heeger, T., Linke, P., Spindler, M. and Thies, A., 1993. *Miliolinella subrotunda* (Montagu), a miliolid foraminifer building large detritic tubes for a temporary epibenthic lifestyle. In: M.R. Langer (Editor), Foraminiferal Microhabitats. *Mar. Micropaleontol.*, 20: 293–301.

Live observations, cytological characteristics and biometrical measurements on *Miliolinella subrotunda* (Montagu, 1803) sampled from the northern and southern Atlantic Ocean are presented. *M. subrotunda* facultatively constructs a long, detritic tube lifting the test several millimeters above the sediment surface. A thickened conical base anchors the construction on the sediment surface and a long, flexible tube protrudes into the velocity profile of the bottom currents. The miliolid test is placed on top, surrounded by the uppermost part of the tube. This construction allows the organisms to feed in the particle stream above the sediment surface. In comparison to species living in and on the surface sediments, *M. subrotunda* apparently shows higher nutritional values in food ingested and larger amounts of reserve substances. Characteristics of the shape and structure that reduce drag on the tubes include a broadened conical base, a flexible tube, and a rounded top. From biometrical measurements it is concluded, that the tubes are constructed over a short period of their ontogeny.

Introduction

Benthic foraminifera utilize a variety of adaptations to access water levels with faster currents, such as settling on stones, algae or macrofaunal hardparts protruding from the sediment surface into the water column. Several agglutinated foraminifera show test constructions raised from the sediment (Lipps, 1983; Altenbach et al., 1988) and one rotaliid is known to use sponge spicules to extend the range of pseudopodial activities (Lutze and Altenbach, 1988). In the case of miliolids, the production of detritic cysts covering the test and part of the surrounding area is well de-

scribed (Rhumbler, 1936). In the present case we focus on a special type of organic, tubiform cyst on which the test is elevated off the sediment surface.

Material and methods

During cruises *Meteor 7*, *Polarstern Ark III/3* and *Poseidon 141* multicorer and grab samples were taken in the northern and southern Atlantic Ocean for studies of deep-sea benthic foraminifera (Table 1). At these locations, visual and microscopic observations of the sediments revealed benthic foraminifera on top of agglutinated tubes extending up from the sediment surface. Live organisms were recovered with needle tweezers from the sediment, covered in seawater, examined under a binocular microscope and preserved for sub-

Correspondence to: A.V. Altenbach, Sonderforschungsbereich 313, Universität Kiel, Olshausenstraße 40/60, 2300 Kiel, Germany.

A THINLY ENCRUSTING DEEP-SEA SPONGE WITH A SPECIAL STRATEGY

Demosponges of the family Hymedesmiidae are of a thinly encrusting (less than 1 mm thick) growth form. About sixty species of the genus *Hymedesmia* have been recorded from sublittoral and bathyal depths of the Greenland and Norwegian Seas, especially from Iceland and parts of the Scandinavian coasts (Alander 1942; Burton 1930, 1959; Lundbeck 1910; Tendal, unpubl.). From depths of more than 2000 m in the Norwegian and Greenland Seas only two species, *Hymedesmia lacera* and *H. stylata*, had been reported. They were described from a station of the Ingolf Expedition, at 2395m, between Iceland and Jan Mayen (Lundbeck 1910).

Although about 80 sponge species were known up to now from the area off West Spitsbergen (Svalbard) (Hentschel 1929; Koltun 1959; Steenstrup & Tendal 1982) not a single hymedesmiid was recorded. We therefore were able to fill a gap in the known distribution of many species, when we, during the Meteor Expedition 13 to that area (July/August 1990), found 14 species of *Hymedesmia*. Nine were recorded at depths between 200 and 600 m, six deeper than 2000 m, but none in between. The six deep-water species came from a single station, at 2360-2616 m. *H. norvegica*, *H. occulta*, *H. similis*, *H. splenium* and *H. sp.* (maybÿ n.sp.) were taken only once while *H. stylata* was also taken at two additional locations, at 2560 and 2570 m. *H. similis* was found also on three stations at 300-500 m (Barthel et al. 1991).

Despite its softness and loose consistency quite a number of *Hymedesmia stylata* specimens were found in the trawl and sledge samples, being one of eight species that by frequency of occurrence and abundance define a widely distributed sponge association in the abyssal basins of the Norwegian and Greenland Seas. While *Hymedesmia* species in general grow on really hard substrate, *H. stylata* is adapted to soft bottom conditions by growing exclusively on a loose accumulation of tests from agglutinated foraminifers and large sand grains. The sponge tissue with the silicious spicule skeleton covers the particles and holds them together so as to form rounded lumps with maximum lengths of up to 15 mm. Although the lumps can attain a thickness of several mm, the layer of tissue is always thin.

Knowledge of the biology of *H. stylata* is fragmentary. The sponge is positioned level with or slightly raised over the surrounding bottom. Pores for the intake of water are distributed all over the surface, and the oscules, which lead away the filtered water, are found on the tip of 2 mm high papillae. The specimens presumably grow slowly. They can be experienced to attain a relatively high age, at least 5 years for the 15 mm large specimens, if comparisons to conditions in shallower depths can be used as a minimum indication (Ayling 1983a, 1983b). Slime is produced all over the surface, probably either as a means of deterring predators and potential epibionts, or in order to deal with particles settling on the surface and threatening to clog the canal system. Larvae were not seen in our specimens, although we found them in several *Hymedesmia* species of the shallow water group.



Hymedesmia stylata on the bottom surface, with accumulated foraminifer tests and sand grains (schematic).



Silicious spicules from *H. stylata*. The curved one is magnified 900 x, the long ones 170 x. (After Lundbeck 1910).

A THINLY ENCRUSTING DEEP-SEA SPONGE WITH A SPECIAL STRATEGY

Demosponges of the family Hymedesmiidae are of a thinly encrusting (less than 1 mm thick) growth form. About sixty species of the genus *Hymedesmia* have been recorded from sublittoral and bathyal depths of the Greenland and Norwegian Seas, especially from Iceland and parts of the Scandinavian coasts (Alander 1942; Burton 1930, 1959; Lundbeck 1910; Tendal, unpubl.). From depths of more than 2000 m in the Norwegian and Greenland Seas only two species, *Hymedesmia lacera* and *H. stylata*, had been reported. They were described from a station of the *Ingolf* Expedition, at 2395m, between Iceland and Jan Mayen (Lundbeck 1910).

Although about 80 sponge species were known up to now from the area off West Spitsbergen (Svalbard) (Hentschel 1929; Koltun 1959; Steenstrup & Tendal 1982) not a single hymedesmiid was recorded. We therefore were able to fill a gap in the known distribution of many species, when we, during the *Meteor* Expedition 13 to that area (July/August 1990), found 14 species of *Hymedesmia*. Nine were recorded at depths between 200 and 600 m, six deeper than 2000 m, but none in between. The six deep-water species came from a single station, at 2360-2616 m. *H. norvegica*, *H. occulta*, *H. similis*, *H. splenium* and *H. sp.* (mayb̄y n.sp.) were taken only once while *H. stylata* was also taken at two additional locations, at 2560 and 2570 m. *H. similis* was found also on three stations at 300-500 m (Barthel et al. 1991).

Despite its softness and loose consistency quite a number of *Hymedesmia stylata* specimens were found in the trawl and sledge samples, being one of eight species that by frequency of occurrence and abundance define a widely distributed sponge association in the abyssal basins of the Norwegian and Greenland Seas. While *Hymedesmia* species in general grow on really hard substrate, *H. stylata* is adapted to soft bottom conditions by growing exclusively on a loose accumulation of tests from agglutinated foraminifers and large sand grains. The sponge tissue with the silicious spicule skeleton covers the particles and holds them together so as to form rounded lumps with maximum lengths of up to 15 mm. Although the lumps can attain a thickness of several mm, the layer of tissue is always thin.

Knowledge of the biology of *H. stylata* is fragmentary. The sponge is positioned level with or slightly raised over the surrounding bottom. Pores for the intake of water are distributed all over the surface, and the oscules, which lead away the filtered water, are found on the tip of 2 mm high papillae. The specimens presumably grow slowly. They can be experienced to attain a relatively high age, at least 5 years for the 15 mm large specimens, if comparisons to conditions in shallower depths can be used as a minimum indication (Ayling 1983a, 1983b). Slime is produced all over the surface, probably either as a means of deterring predators and potential epibionts, or in order to deal with particles settling on the surface and threatening to clog the canal system. Larvae were not seen in our specimens, although we found them in several *Hymedesmia* species of the shallow water group.



Hymedesmia stylata on the bottom surface, with accumulated foraminifer tests and sand grains (schematic).



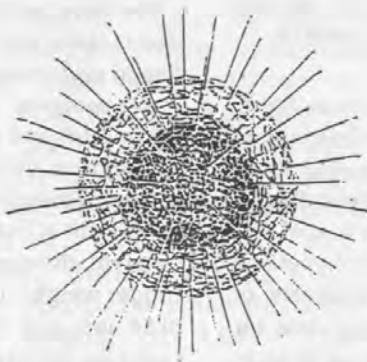
Silicious spicules from *H. stylata*. The curved one is magnified 900 x, the long ones 170 x. (After Lundbeck 1910).

Literature

- Alaner, H., 1942: Sponges from the Swedish west-coast. - Göteborg. 95pp.
- Ayling, A.L. 1983a: Growth and regeneration rates in thinly encrusting demospongiae from temperate waters. - Biol. Bull. 165: 343-352.
- 1983b: Factors affecting the spatial distributions of thinly encrusting sponges from temperate waters. - Oecologia 60: 412-418.
- Barthel, D., O.S. Tendal & U. Witte, 1991: Faunistik, Biologie, Ökologie und Spikula-Lieferung von Schwämmen. - Ber. Sonderforsch.bereich 313. Meteor-Ber. Nr. 91. Reise Nr. 13. (In press).
- Burton, M., 1930: Norwegian sponges from the Noërman collection. - Proc. Zool. Soc. Lond. 1930, part 2: 487-546.
- 1959: Spongia. - Zool. Iceland II. Part 3-4: 1-71.
- Hentschel, E., 1929: Die Kiesel- und Hornschwämme des nördlichen Eismers. - Fauna Arct. 5: 857-1042.
- Koltun, V.M., 1959: Cornacuspongida of the northern and far east seas of the USSR. - Akad. NAUK 90: 1-227. (In Russian).
- Lundbeck, W., 1910: Porifera, Desmacidonidae (Pars). - Dan. Ingolf-Exped. 6, part 3: 1-124.
- Steenstrup, E. & O.S. Tendal, 1982: The genus *Thenia* (Porifera, Demospongia, Choristida) in the Norwegian Sea and adjacent waters; an annotated key. - Sarsia 67: 259-268.

Dagmar Barthel
Inst. für Meereskunde
an der Universität Kiel
Germany

Ole Tendal
Zoological Museum
University of Copenhagen
Denmark



CRUISING ON CUMULUS

Cumulus is one of the Meteorological Office's Ocean Weather ships. She is stationed in the Northeast Atlantic at Ocean Station LIMA (55°N, 20°W). She makes routine port calls at Greenock. At the present time she has 20 spare berths which Oceanscan Master Services Ltd can offer to researchers and students. The company offers taught courses in marine science and technology, observational methods and the realities of sea-going. Alternatively, clients can take the ship on a facilities-only basis, in order to put on their own courses. The company is also able to take observers who want to enjoy the experience of sailing on an ocean weather ship and learn about her operation.

For research workers and people who want to test or calibrate equipment, *Cumulus* offers an excellent and cheap platform, costing a fraction of the price of a dedicated oceanographic research ship. Brochures with descriptions of the ship and her facilities and details of costs of trips for individuals or groups, can be obtained from Oceanscan Master Services Ltd, POBox 63, Godalming GU8 5TQ, UK, or phone 0483 860351.

Tony Rice
IOS, Wormley

NOTE

New information on the biology of Antarctic deep-water sponges derived from underwater photography

Dagmar Barthel¹, Julian Gutt², Ole S. Tendal³¹ Dept of Marine Botany, Institut für Meereskunde, Düsternbrooker Weg 20, D-2300 Kiel, Germany² Alfred-Wegener-Institut für Polar- und Meeresforschung, Columbusstr., D-2850 Bremerhaven, Germany³ Zoologisk Museum, Universitetsparken 15, DK-2100 Copenhagen O, Denmark

ABSTRACT: Aspects of the biology of sponges from deeper parts of the Antarctic Weddell Sea, documented by underwater photography, are described and compared to material from bottom trawling. The photographs provide new, important information on the biology and ecology of Antarctic sponges, such as positioning on the sea bottom, live body form and dimensions, as well as on the degree of body surface fouling. Such information is not obtainable from trawled material.

During Leg III of the European Polarstern Study (EPOS), about 1500 pictures of the Weddell Sea bottom along transects at Halley Bay, Vestkapp and Kapp Norvegia were taken in depths between 100 and 1200 m at 24 stations (Arntz et al. 1990). The main aim of this effort was to elucidate small- and large-scale variations in species composition and community structure of Antarctic benthos and to provide additional data for biomass estimates of the larger benthic organisms in areas that are out of a diver's reach and can only be sampled by bottom trawling, box cores, etc.

One of the main target groups were sponges (Arntz et al. 1990), which greatly contribute to the 'multi-storied' (Knox 1970) structure of Antarctic benthic communities, characterized by high diversity, patchy distributions, little infauna, as well as a high degree of eurybathy and slow growth of most of its members (see reviews by Picken 1984 and White 1984). The large hexactinellids which are dominant in many Antarctic habitats (e.g. Beliaev & Ushakov 1957, cited in Gallardo 1987, Dayton et al. 1970, Koltun 1970) including the eastern Weddell Sea shelf (Voss 1988) have repeatedly been documented in bottom photographs (e.g. Bullivant 1961, Dearborn 1977, Dayton 1979) while demosponges, which contribute far more species, have received less attention.

A first step towards a numerical analysis of our photographs was the task of recognizing species on the

basis of material taken from trawls during the same cruise, mostly from the same stations. The pictures provided valuable information on the biology of Antarctic sponges and helped to answer some of the questions posed by work on trawled material.

We here present a few 'case studies' in order to demonstrate the potential of photographic documentation in understanding the biology and ecology of deep-water sponges.

Material and methods. Square photographs (Kodak Ektachrome 64) were taken with a 70 mm underwater camera (Hasselblad 500 EL/M with Metz mecablit 40 CT4 flash) (Gutt 1988). The shutter was released at a constant distance from the sea floor by means of a trigger weight. Thus, the size of the photographed area (0.56 m²) and the size of the photographed objects could be calculated. Pictures were taken 'blind' without control over the exact sampling place. For details of methods see Hersey (1967) and Heezen & Hollister (1971). Specimens were collected with Agassiz and bottom trawls towed for ca 1 h at a speed of 1 knot.

'Case study' 1. *Cinachyra antarctica* (Carter, 1872). Common occurrence in many Antarctic areas at depths from 18 to 780 m (Koltun 1966, present study). Diagnosis (by Koltun):

'Body more or less rounded, maximum diameter 6 cm. Surface with conules bearing long bundles of spicules at their tips. Conules situated obliquely and disposed in a spiral pattern. The bundles of spines are especially long in the inferior part of the body where they form a radicular tangle. Among the conules there are round or oval areas (up to 0.5 cm diameter) which are covered with pores. There is also an oscular surface which has a maximum diameter of 3.25 mm. Color [Koltun refers to alcohol preserved material]: gray, grayish brown or light brown. Skeleton radial-spiral.'



BARTHEL, D. & O. TENDAL (1993). Sponge spicules in abyssal and bathyal sediment of the NE Atlantic. Deep-Sea Newsletter 20: 15-18.

SPONGE SPICULES IN ABYSSAL AND BATHYAL SEDIMENTS OF THE NE ATLANTIC

Siliceous sponge spicules are concurrently mentioned in deep-sea expedition reports as constituents of abyssal and bathyal sediments, although generally comprising only a few percent of the single samples.

Abyssal and lower bathyal depths

In the North Atlantic, a very comprehensive documentation has been given by Murray & Chumley (1924). In 1426 samples, mostly from north of the Equator, they found sponge spicules in 1365 (96%). All the localities were at depths greater than about 200 m, and by far the largest number came from more than 1000 m depth.

Murray & Chumley (1924) mention only few localities north of 50°N, but the results from the Danish Ingolf Expedition 1895-96 support their main views as far as to 70°N. Boeggild (1900) found in the *Ingolf* material that out of the 143 stations taken, samples from 90 (63%) contained sponge spicules; of the 80 stations taken deeper than 1000 m, 64 (80%) contained spicules.

Dahl et al. (1976) mentioned "fairly large quantities of sponges, especially in the trawl samples from the Greenland basin", taken by the NORBI Expedition; most of these are spicule masses and dead skeletons (Tendal, unpubl.). In the report from the Norwegian North-Atlantic Expedition 1876-78 Schmelck (1882) stated that at depths greater than about 1800 m "most of the samples were found to contain delicate spicules of sponges"; the expedition worked in the whole area east of the island of Jan Mayen, from West Spitzbergen to the Norwegian coast. Barthel et al. (1991) found spicules in all sediment samples from bathyal and abyssal depths off West Spitzbergen. During the YMER-80 Expedition spicule masses and dead skeletons were taken at 1000-3900 m in the Nansen Basin of the Polar Sea (Tendal, unpubl.). Our general observations during several cruises with the "Håkon Mosby" (University of Bergen) indicate that siliceous sponge spicules are common in abyssal samples from the Iceland Sea and parts of the Norwegian Sea.

The taxonomic identity of the spicules is stated for only few of the samples mentioned in the literature. In broad terms spicules from abyssal depths south of the Scotland-Faroes-Iceland-Greenland Ridge complex seem to come from hexactinellids, as do most of those found in the Iceland, Greenland and Polar Seas, while those from the Norwegian Sea and the area off West Spitzbergen appear to be mostly from choristids and other demosponges.

Upper bathyal and lower shelf depths

Here, sponge spicules have been found in the sediments of many places in the NE Atlantic, the amount varying from loose single spicules to mass occurrences, sometimes forming felt-like layers. Reports on mass occurrences so far are very scattered, and the taxonomic identity is not always stated: Off Mauretania, 800-900 m, hexactinellids (Lutze & Thiel 1989); Porcupine Seabight, 1000-1300 m, hexactinellids (Bett et al. 1992; Bett & Rice 1992; Rice et al. 1990); off Scotland, 800 m, hexactinellids (Thomson 1870); between Scotland and the Faroes, 700-1000 m, hexactinellids (Schulze 1882); several places around the Faroes, 300-900 m, choristids (our observations); north of the Faroes, 890-1300 m (Boeggild 1900); north of Iceland, 500 m, demosponges (our observations); southwest of Iceland, 1000-1200 m, hexactinellids (our observations); south of Iceland, 1200 m, demosponges (our observations); between Iceland and Greenland, 220-365 m (Boeggild 1900); all the way from Spitzbergen to western Norway, roughly between 900 and 2000 m, Schmelck (1882) found what he called "transition clay".... "which is absolutely interwoven with these minute silicious needles, so that, on touching the dried bottom sample, the hand gets covered with them."; several places along the edge of the Norwegian Trough, 500-700 m (T. Brattegard, pers. comm.); Tromsøflaket off northern Norway, 280 m, demosponges (Könnecker 1989); off Finmark up to 70°N, about 200-400 m (Schmelck 1882, Rezvoj 1928, Zenkevitch 1963); off West Spitzbergen, 400 m downwards (Schmelck 1882; demosponges, Barthel et al. 1991); north of Spitzbergen, 650-1000 m, hexactinellids (Schulze 1900, Hentschel 1929).

Autochthonous and allochthonous spicule deposition

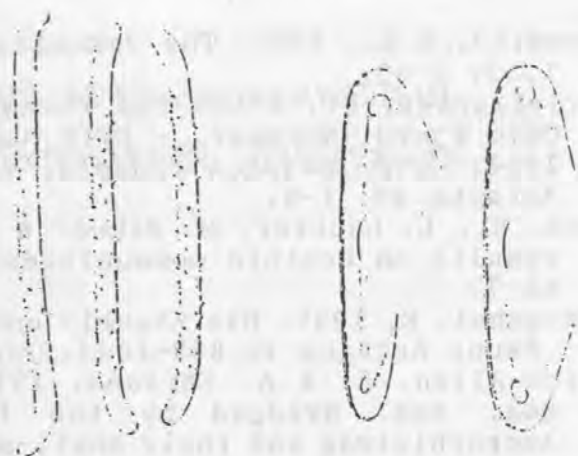
It is our impression that at abyssal depths the spicules set free after the death of the sponges are mainly deposited locally. One example is extensive beds of *Caulophacus* (Hexactinellida) stalks and loose spicules in the deepest parts of the Greenland Sea, where the sponge is abundant. Another is stalks of *Hyalonema* (Hexactinellida) commonly dredged in some areas of the abyssal plains of the North Atlantic.

Along the continental slope, downward transport of spicules can be caused by currents, resuspension and sediment gliding. Local topography and hydrographic events define the spreading pattern. An example is from the Faroes, where in some places choristid sponges are found at about 250 m depth on gravel, and spicules of choristid types occur as thin mats on the soft sediment only few km away at 350-400 m depth (own observations). A second example is from between Spitzbergen and Björnøya, where large amounts of sediment are transported away from land into the deep Norwegian Sea, probably by cascading of very cold water from the Barents Sea shelf. Choristid and other demosponge spicule types are here found very far at sea, at depths where the sponges in question do not live (Barthel et al. 1991) (Fig. 1). If in such cases recognizable spicules are abundant and the distribution of sponges living in the area is known, the occurrence of the spicules can be taken as an indication of the direction and distance of the sediment transport.

Figure 1. Examples of spicules found at 2500 m depth off Bjørnøya.

Left: macroscleres (skeleton spicules), 200-240 μm long, from *Metschnikowia spinispiculum* Carter, 1876. The species is known from the western Barents Sea at about 200 m depth.

Right: microscleres (free spicules), 140-200 μm long, from *Hamacantha* sp. *Hamacantha* has not been taken in the area, but in the southwestern Barents Sea down to about 360 m.



Ecological importance

Where sponge spicules occur in large masses, and particularly where they form thick coherent mats, they have a profound effect on the physical properties of the bottom and on the composition of the local fauna (Barthel 1992, Barthel & Gutt 1992).

In localities where spicules are abundant, but do not form coherent mats, their biological impact is more difficult to assess. They seem to give the bottom a loose structure, making it easier for small organisms to find space. One might also expect the activities of larger mud eaters and burrowers to be influenced. A certain vertical sorting and concentration of spicules in distinct layers is sometimes seen in box cores, and may be caused by bioturbation (J. Rumohr, pers.comm.).

For some foraminifers sponge spicules are a suitable substrate (Jumars & Eckman 1983, Lutze & Thiel 1939), while others use spicules from the sediment as material for their agglutinated tests (examples are found in: Christiansen 1958, 1964 and Heron-Allen & Earland 1912). There are also cases of use of sponge spicules for more special purposes, such as expanders for the pseudopodial network (Lutze & Altenbach 1988). Certain sponges use foreign spicules instead of own spicules in their skeleton fibers, and in such cases spicules of many different origins can be found together (Barthel et al. 1991).

Dagmar Barthel
Institut für Meereskunde, Kiel

Ole Tendal
Zoologisk Museum, København

References

- Barthel, D., 1992: Do hexactinellids structure Antarctic sponge associations? - *Ophelia* 36: 111-118.
Barthel, D. & J. Gutt, 1992: Sponge associations in the eastern Weddell Sea. - *Antarctic Science* 4: 137-150.
Barthel, D., O.S. Tendal & U. Witte, 1991: Faunistik, Biologie, Ökologie und Spicula-Lieferung von Schwämmen. - *Meteor-Berichte* Nr. 91-92: 37-48. Institut für Meereskunde an der Universität Hamburg.
Bett, B.J., M.H. Thurston & A.L. Rice, 1992: Sponge surprise. - *Deep-Sea Newsletter* No. 19: 19.
Bett, B.J. & A.L. Rice, 1992: The influence of hexactinellid sponge (*Pheronema carpenteri*) spicules on the patchy distribution of macrobenthos in the Porcupine Seabight (bathyal NE Atlantic). - *Ophelia* 36: 217-226.

- Boeggild, O.B., 1900: The deposits of the sea-bottom. - Dan. Ingolf-Exped. I, 3: 1-89.
- Christiansen, B., 1958: The Foraminifer fauna in the Dröbak Sound in the Oslo Fjord (Norway). - Nytt Mag. Zool. 6: 5-91.
- 1964: *Spiculosiphon radiata*, a new foraminifer from northern Norway. - Astarte 25: 1-8.
- Dahl, E., L. Laubier, M. Sibuet & J.-O. Strömberg, 1976: Some quantitative results on benthic communities of the deep Norwegian Sea. - Astarte 9: 61-79.
- Hentschel, E., 1929: Die Kiesel- und Hornschwämme des Nördlichen Eismeers. - Fauna Arctica V: 859-1042.
- Heron-Allen, E. & A. Earland, 1912: On some Foraminifera from the North Sea, etc. dredged by the Fisheries "Goldseeker". I. On some new Astrorhizidae and their shell-structure. - J. roy. micr. Soc. 1912: 382-389.
- Jumars, P.A. & J.E. Eckman, 1983: Spatial structures within deep-sea benthic communities. - Chapter 10 (pp. 399-451) in: The Sea, vol 8. Deep-sea Biology. John Wiley & Sons, New York, 560 pp.
- Könnecker, G., 1989: *Plectroninia norvegica* sp. nov. (Calcarea, Minchinellidae), a new 'Pharetronid' sponge from the North Atlantic. - Sarsia 74: 131-135.
- Lutze, G.F. & H. Thiel, 1989: Epibenthic Foraminifera from elevated microhabitats: *Cibicidoides wuellerstorfi* and *Planulina ariminensis*. - J. Foram. Res. 19: 153-158.
- Lutze, G.F. & A.V. Altenbach, 1988: *Rupertina stabilis*, a highly adapted, suspension feeding foraminifer. - Meyaniana 40: 55-69.
- Murray, J. & J. Chumley, 1924: The deep-sea deposits of the Atlantic Ocean. - Trans. roy. Soc. Edinburgh 54: 1-252.
- Rezvoj, P., 1928: Contribution to the fauna of Porifera in the Barents Sea. - Trans. Inst. Sci. Expl. North 37: 67-95 (In Russian).
- Rice, A.L., M.H. Thurston & A.L. New, 1990: Dense aggregations of a hexactinellid sponge, *Pheronema carpenteri* in the Porcupine Seabight (north-east Atlantic Ocean), and possible causes. - Prog. Oceanogr. 24: 179-196.
- Schmelck, L., 1882: Chemistry II. On oceanic deposits. - The Norwegian North-Atlantic Expedition 1876-1878. Christiania. 71 pp.
- Schulze, F.E., 1882: Report on the sponges. - P. 708 in: R.N. Tizard & J. Murray: Exploration of the Faroe channel, during the summer of 1880, in H.M.'s hired ship "Knight Errant". - Proc. roy. Soc. Edinburgh 11: 638-717.
- 1900: Die Hexactinelliden. - Fauna Arctica I: 85-108.
- Thomson, W., 1870: On *Holtenia*, a genus of vitreous sponges. - Phil. Trans. roy. Soc. London 159: 701-720.
- Zenkevitch, L., 1963: Biology of the Seas of the U.S.S.R. - George Allen & Unwin. 955 pp.



DEEP-SEA HYDROTHERMAL LANDSCAPES

Modern submersibles afford a unique opportunity for direct close-up study of deep-sea landscapes. Because of this, the microdistribution of animal populations with respect to each other and to environmental conditions (bottom topography, currents, etc.) has become an important aspect of international deep-sea research.

THE SPONGE ASSOCIATION OF THE ABYSSAL NORWEGIAN-
GREENLAND SEA: SPECIES COMPOSITION, SUBSTRATE
RELATIONSHIPS AND DISTRIBUTION

DAGMAR BARTHEL & OLE SECHER TENDAL

ABSTRACT

During the 'Meteor' expedition 13 in July and August 1990 to the northern part of the Norwegian Sea off west Spitsbergen, 7 stations with a depth of 2000 m or more were sampled with Agassiztrawl or hyperbenthos sledge, 14 more with a large box corer. Sponges were found at 6 of the trawl stations and in 2 box cores. A total of 19 species occurred, most of which were new to the area. Eight of the species were encountered more often than the other 11. Literature review and check of unpublished samples showed that by distribution, frequency of occurrence or abundance these species can be defined as the typical sponge association of the Norwegian and Greenland abyssal sea. This sponge association has a wide occurrence over the deep Norwegian-Greenland seas and parts of the Arctic basins. The analysis of substrate utilization of the 8 core species shows that all of them are able to colonize soft bottom, even some that previously had been considered to be dependent on hard substrate exclusively. Alternative substrate utilization and, in some species, the adoption of an infaunal life style are judged to be major reasons for the success of these species in the deep sea. The infaunal life style of the species *Thenia abyssorum*, *Radiella sol* and *Tentorium semisuberites* is documented and population structure data are given for the first time.

**Redescription of *Janiralata pulchra* (Hansen, 1916) (Janiridae) from
the Kolbeinsey-Ridge, North Atlantic and synonymy with *Ianthopsis*
pulchra (Acanthaspidiidae) (Crustacea, Isopoda)**

Angelika Brandt

Institute for Polar Ecology

University of Kiel

Seefischmarkt

Geb. 12

D-2300 Kiel

Germany

Im Druck bei Ophelia

Abstract: This paper deals with a poorly known species, *Janthopsis pulchra* (Hansen, 1916), found on the Kolbeinsey Ridge, north of Iceland (North Atlantic) during the expedition M21-5 with RV *Meteor*. The species was thought to be a member of the family Acanthaspidiidae, however, a detailed study, including comparison with the type material of Hansen from the Ingolf expedition, and redescription with complete illustration document, that this species belongs to the Janiridae.

Introduction:

Specimens of the poorly known janirid species - *Ianthopsis pulchra* (Hansen, 1916) (Asellota, Isopoda, Crustacea) - were discovered in an epibenthic sledge collection from the eastern Kolbeinsey-Ridge, north of Iceland. The existing descriptions of this species are brief and incomplete, with illustrations of only the dorsal view. Only some mouthparts and appendages have been illustrated using very small figures without any detailed setation, which is an important feature both for taxonomy and phylogeny (e. g. Brandt, 1988, 1992a).

Specimens of this species have been found around South Greenland in the Davis Strait until now, but not further north than 65°N. It has now been sampled during the cruise of RV "Meteor" (M21-5) on a station off the Kolbeinsey-Ridge, north of Iceland. As the species has not yet been fully described, it was difficult to place it into a definite genus. Hansen (1916) described the species as a member of the genus *Janira* and later Wolff (1962) synonymized *Janira pulchra* with *Ianthopsis*, but did not present a redescription. Brandt (1991) presented a review of the Acanthaspidiidae, in which *Ianthopsis pulchra*

***Notophryxus clypeatus* Sars, 1885, a parasitic isopod of
mysidaceans (Crustacea, Peracarida) from the Kolbeinsey Ridge,
north of Iceland**

by

Angelika Brandt

Institut of Polar Ecology

University of Kiel

Seefischmarkt, Geb. 12

D-2300 Kiel 14

Germany

eingereicht bei Sarsia

Brandt, A. XXX. *Notophryxus clypeatus* Sars, 1885, a parasitic isopod of mysidaceans (Crustacea, Peracarida) from the Kolbeinsey Ridge, north of Iceland.-
Sarsia XXX.

Summary

Notophryxus clypeatus (Crustacea, Isopoda) has been found on the Kolbeinsey Ridge, north of Iceland parasitizing on the mysid *Pseudomma truncatum* Smith, 1879. A study of the morphology of this poorly known and seldomly reported species is presented in line drawings and SEM pictures.

Angelika Brandt, Institute of Polar Ecology, University of Kiel, Seefischmarkt,
Building 12, Wischhofstraße 1-3, W-2300 Kiel 14, Germany.

**Composition, abundance, and diversity of peracarid crustaceans
from the Kolbeinsey Ridge, north of Iceland**

by

Angelika Brandt
Institute of Polar Ecology
University of Kiel
Seefischmarkt, Geb. 12
Wischhofstraße 1-3
D-2300 Kiel 14

im Druck bei Polar Biology

Summary. Composition, abundance, and diversity of Crustacea Peracarida were investigated on a transect across the Kolbeinsey Ridge, north of Iceland in summer 1992 during the M21/5 expedition with RV *Meteor*. This ridge is influenced by both the cold East Greenland Current as well as the warmer East Iceland Current, mixing with warmer Atlantic water. Sampling has been performed using an epibenthic sledge modified after Rothlisberg & Percy (1977). The peracarid crustaceans are one of the most important components of the macrobenthic epi- and suprafaua. Their composition, abundance, and diversity was significantly different on western and eastern sides of the slope. Isopoda and Amphipoda were most frequent at all stations, followed by Cumacea, and Tanaidacea. Mysidacea have only been sampled on the eastern slope. Abundance and diversity were highest on the two eastern stations in depths of 830 - 940 meters, values decreased on the deepest eastern station in 1100 meter depth and were also low on both western stations in 830 and 860 meters depth. These differences are probably due to sediment composition and to quality and quantity of organic carbon reaching the seafloor, rather than to differences in salinity or in hydrographic regimes. The high abundance of peracarid crustaceans, especially of epibenthic species, capable of burrowing within the upper centimeters of sediment, indicate their high potential for bioturbation and also their importance for benthic carbon cycling.

Introduction

The marine environment of the western Greenland-Iceland-Norwegian (GIN) seas is characterized by extremely cold polar water masses, long periods of ice cover, large seasonal fluctuations in light regime and, hence, generally low biological activity (Hempel 1985). Recent investigations have revealed, however, that benthic communities can be surprisingly rich both in biomass and in diversity at various locations on the Greenland shelf as well as on the continental and mid-ocean-ridge slopes (Piepenburg 1988, Svarvarsson et al. 1990). These assemblages are supposed to be fed by the high surplus primary production of nearby marginal ice zones either of the East Greenland Current or of polynya regions. There is evidence that a large amount of the organic material produced in the ice or at the ice edges tends to precipitate from the euphotic layer in strongly pulsed sedimentation events (Hebbeln

REDESCRIPTION OF *JANIRALATA PULCHRA*
(HANSEN, 1916) (JANIRIDAE)
FROM THE KOLBEINSEY RIDGE, NORTH ATLANTIC
AND SYNONYMY WITH *IANTHOPSIS PULCHRA*
(ACANTHASPIDIIDAE) (CRUSTACEA, ISOPODA)

Angelika Brandt

Institute for Polar Ecology, University of Kiel, Seefischmarkt Geb. 12, D-2300 Kiel, Germany

ABSTRACT

This paper deals with a poorly known species, *Ianthopsis pulchra* (Hansen, 1916), found on the Kolbeinsey Ridge, north of Iceland (North Atlantic) during the expedition M21-5 with RV *Meteor*. The species was thought to be a member of the family Acanthaspidiidae, however, a detailed study, including comparison with the type material of Hansen from the Ingolf expedition and redescription with complete illustration, document that this species belongs to the Janiridae.

INTRODUCTION

Specimens of the poorly known janirid species - *Ianthopsis pulchra* (Hansen, 1916) (Asellota, Isopoda, Crustacea) - were discovered in an epibenthic sledge collection from the eastern Kolbeinsey Ridge. The existing descriptions of this species are brief and incomplete, with illustrations of only the dorsal view. Only some mouthparts and appendages have been illustrated using very small figures without any detailed setation, which is an important feature both for taxonomy and phylogeny (e.g. Brandt 1988, 1992a).

Specimens of this species have been found around South Greenland in the Davis Strait until now, but not further north than 65°N. It has now been sampled during the cruise of RV "Meteor" (M21-5) on a station off the Kolbeinsey Ridge, north of Iceland. As the species has not yet been fully described, it was difficult to place it into a definite genus. Hansen (1916) described the species as a member of the genus *Janira* and later Wolff (1962) synonymized *Janira pulchra* with *Ianthopsis*, but did not present a redescription. Brandt (1991) presented a review of the Acanthaspidiidae, in which *Ianthopsis pulchra* still belonged to this family. However, in 1992 Brandt already doubted that this species belongs to the acanthaspidiids (Brandt 1992b: 159) and placed it "incertae sedis". It is indeed very difficult to place this species into a genus proper, because its propodus of pereop-

Peracarid crustacean assemblages of the Kolbeinsey Ridge, north of Iceland

Angelika Brandt, Dieter Piepenburg

im Druck bei Polar Biology

Institut für Polarökologie der Universität Kiel, Wischhofstraße 1-3 (Geb.12), W-2300 Kiel 14, Germany

Summary

On the Kolbeinsey Ridge 92 species of peracarid crustaceans have been sampled at five stations by means of the epibenthic sledge. For an analysis of the multispecies distribution pattern across the ridge, a total of 46 species have been considered, which occurred at least at two stations and with $\geq 5\%$ significance. The analysis revealed four assemblages: a deep species assemblage, an eastern slope assemblage, an ubiquitous species assemblage and a Western Slope Assemblage. The western slope assemblage consists mainly of Amphipoda, which were most abundant and diverse on the western slope. The ubiquitous and eastern slope assemblages, however, are dominated by Isopoda, which also comprised most species and individuals on the eastern slope. Cumaceans were the most representative species of the deep species assemblage. These differences in species composition and abundance can probably be attributed to food supply and sediment composition, rather than to salinity or bottom water temperature.

Introduction

Benthic communities can be surprisingly rich in biomass and diversity at many locations on the Greenland shelf as well as on the continental and mid-ocean ridge slopes (Piepenburg 1988, Svarvarsson et al. 1990), although the marine environment of the western Greenland-Iceland-Norwegian (GIN) seas is characterized by extremely low, but fairly constant temperatures, long periods of ice cover, large seasonal fluctuations in light regime and, hence, generally only low biological activity (Hempel 1985). These assemblages are probably nourished by the high primary productivity of nearby marginal ice zones either of the East Greenland Current or of polynya regions. A high amount of the organic material produced in the ice or at the ice edges is sinking in strongly pulsed sedimentation events (Hebbeln and Wefer 1991). Reaching the benthic nepheloid layer (BNL) the bulk of suspended matter is laterally distributed, mostly by topography-driven currents in certain depth zones, to the areas of eventual deposition (Graf 1992; Wainwright 1990). Quality and quantity of organic carbon reaching the seafloor has a direct effect on the benthic communities (Carey 1991; Graf 1989; 1992; Grebmeier et al., 1988; Suess 1980).

It is, therefore, hypothesized that differences in sedimentation regimes have a strong impact on benthos. To assess this relationship a benthic meso-scale case study was

THE ROLE OF BENTHIC FORAMINIFERA IN DEEP-SEA FOOD WEBS AND CARBON CYCLING

ANDREW J. GOODAY

*Institute of Oceanographic Sciences Deacon Laboratory
Brook Road
Wormley, Godalming
Surrey, GU8 5UB
United Kingdom*

LISA A. LEVIN

*Department of Marine, Earth and Atmospheric Sciences,
North Carolina State University
Raleigh, NC 27695-8208
U.S.A.*

PETER LINKE and THOMAS HEEGER

*Institut für Meereskunde,
Düsternbrooker Weg 20
2300 Kiel,
Germany*

ABSTRACT. Benthic foraminifera are a major element in deep-sea sediment and hard-substrate communities, sometimes accounting for 50% or more of eukaryotic biomass. They feed at a low trophic level, consuming mainly planktonic and other detritus and bacteria. Some species have metabolic adaptations enabling them to respond quickly to pulsed detrital inputs with rapid rates of reproduction and growth. These foraminifera probably assist microorganisms in the breakdown of fresh detrital material, while others are deposit feeders which convert more refractory organic substances into biomass. DOM uptake may be important, although no data exist as yet to substantiate this. Foraminifera are consumed by a wide variety of organisms, including selective and non-selective deposit feeders and specialised predators, and probably represent an important link between lower and higher levels of deep-sea food webs. A variety of non-trophic interactions between metazoans and foraminifera, for example, the provision of physical substrates, may facilitate access to enhanced food supplies. Thus, foraminifera play a largely unquantified but potentially significant role in deep-sea carbon cycling.

1. Introduction

Foraminifera are heterotrophic, amoeboid protozoa, generally considered to be characterised by the presence of granuloreticulate pseudopodia, a test with one or more chambers, and, in at least some species, by an alternation of sexual and asexual generations (Bock et al. 1985). However,

BENTHIC-PELAGIC COUPLING: A BENTHIC VIEW

GERHARD GRAF

*GEOMAR, Research Center for Marine Geosciences Wischhofstraße 1–3, 2300 Kiel
14, Germany*

ABSTRACT Benthic-pelagic coupling is described on a community level reviewing examples from Kiel Bight (Baltic Sea) and the Norwegian Greenland Sea. An energy flow equation for marine sediments is developed, analogous to the one for animals, which includes processes such as biodeposition, sedimentation, as well as lateral advection, all types of bioturbation, and physical transport mechanisms through the sediment–water interface. The fast response and deep-reaching effects of sedimentation events, the budget problem, and the importance of lateral advection as well as resuspension for the understanding of a marine soft-bottom ecosystem are discussed.

INTRODUCTION

Heterotrophic life in the aphotic benthic zone of the sea is based on primary production that takes place in the euphotic pelagic or benthic zones. Thus, the mere existence of the aphotic way of life is already proof of transport mechanisms that couple the primary production zones with exclusively secondary production habitats. Although during recent years, with the detection of deep-sea vents and subduction zones, other energy and carbon sources for benthic life have been described, organic matter (OM) produced in the pelagic zone is the beginning of the benthic food web in most cases. Until the 1970s the flow of matter from the pelagial to the benthic zone was believed to be a steady rain of particles that settle vertically to the sea floor (cf. Steele, 1974). Remane (1940), however, reported that the sediment he collected in Kiel Bight during spring was covered by a greenish layer derived from pelagic diatoms. This indicates that there may be some imbalances in the particle rain. In lakes, Jonasson (1964) described the influence of settling spring and autumn plankton blooms on the development of Chironomidae larvae in the sediment.

Qualitatively there was never any doubt about the dependence of benthic life on pelagic processes and the above statements may be regarded as trivial. Things grew complicated, however, when attempts were made to develop a quantitative description of benthic-pelagic coupling. Hargrave (1973) described a model in which pelagic primary production is related to the oxygen demand of the sediment; as a third variable he introduced the depth of the mixed layer in the water column.

ADENOSINE NUCLEOTIDES AS INDICATORS OF DEEP-SEA BENTHIC METABOLISM

G. GRAF¹ and P. LINKE²

¹GEOMAR Research Center
Wischhofstr. 1-3,
2300 Kiel 14
F.R.Germany

²Sonderforschungsbereich 313
Heinrich-Hecht Platz 10
2300 Kiel 1
F.R.Germany

ABSTRACT. At 12 locations on the Antarctic cruise 56/2 with *RV Meteor* extremely low ratios of the adenosine nucleotides ATP : AMP were found in surface sediments ranging from 0.03 to 0.28. The same low ratios were measured in isolated benthic foraminifera, *Cribrostomoides subglobosum*, from the Vøring-Plateau (Norwegian-Greenland Sea). These organisms showed a physiological awakening response to input of organic matter by phosphorylation of AMP to ATP. They increased their ATP levels within a factor of ten in 20 days. The same strong increase in ATP content was also described from sediments of the same area after the deposition of faecal pellets. Thus, the rapid changes in adenosine nucleotide levels and the ATP : AMP ratio are good indicators of deep-sea benthic metabolism.

1. Introduction

The strong seasonality of food supply in polar and subpolar regions of the deep sea (Wefer *et al.* 1988, Bathmann *et al.* 1990) means that benthic organisms must be specially adapted in order to survive long periods of low food supply and to compete during those short periods when food becomes plentiful. A similar problem exists for deep-sea scavengers, which depend on occasional food falls. Smith and Baldwin (1982) described the strategy of these organisms, which have developed special adaptations in terms of respiratory activity, behaviour and morphology.

In this paper we describe some biochemical results which help to explain the adaptation of deep-sea benthic organisms to fluctuations in food supply. During a cruise to the Antarctic in 1981 some unusual adenosine nucleotide values were obtained, showing very high AMP concentrations and low ATP : AMP ratios. Recent results from sediments and isolated benthic foraminifera from the Norwegian-Greenland Sea may provide an appropriate explanation.

In shallow waters the nucleotide pool of protozoans such as rhizopods and ciliates represents an intermediate position between bacteria and metazoans (Linke 1986, Sich 1985). In the deep sea, benthic foraminifera respond rapidly to the deposition of phytodetritus (Gooday 1988). Since foraminifera are extremely abundant in Arctic regions (Fetter 1973, Basov and Khusid 1983), it is likely that these organisms exhibit special adaptations to life in polar deep-sea environments.

Nine new and less known nematode species from the deep-sea benthos of the Norwegian Sea

Preben Jensen

Marine Biological Laboratory, University of Copenhagen, Strandpromenaden 5, DK-3000 Helsingør, Denmark

Received 23 August 1990; accepted 12 December 1990

Key words: Norwegian Sea, deep-sea, nematodes, new species

Abstract

Eight new and one less known nematode species are described from Vøring Plateau at 970 m to 1426 m depth and adjacent deep-sea plain at 3062 m depth in the Norwegian Sea: *Actinonema grafi* sp. nov., *Desmodora pilosa* Ditlevsen, 1926, *Leptolaimus meyer-reili* sp. nov., *Tarvaia heegeri* sp. nov., *Diplopeltoides linkei* sp. nov., *Diplopeltis bathmanni* sp. nov., *Southerniella nojii* sp. nov., *Pararaeolaimus rumohri* sp. nov. and *Theristus altenbachii* sp. nov. Differential diagnoses to the eight new species are given.

Actinonema grafi, *Leptolaimus meyer-reili* and *Theristus altenbachii* are frequently found on Vøring Plateau and belong to the most dominant species, whereas *Desmodora pilosa* and *Pararaeolaimus rumohri* are dominant species at few sites only. The other species occur sporadically, in few numbers, and belong – as do *Pararaeolaimus rumohri* – to seldomly reported nematode genera.

Introduction

A large collection of nematodes was sampled during two cruises of R/V *Meteor* in 1986 and 1988 to the Norwegian Sea because nematodes turned out to be suitable biological tools in discriminating environmental heterogeneity in the deep-sea benthos (cf. Jensen, 1988a; Jensen *et al.*, 1991). More than 100 nematode species were found of which only few species were known (cf. Jensen, 1988b, 1991a). Present study includes the descriptions of eight new species and redescription of a poorly known species, and is part of a series of papers describing nematode species from the

deep-sea benthos of the Norwegian Sea (Jensen, 1988b, 1991a,b).

Material and methods

Benthos samples were collected with a box corer (50 cm × 50 cm × 50 cm) from R/V *Meteor* during a cruise from 19 June to 2 July 1986 in the Norwegian Sea. Further samples were obtained with a multicorer (a series of cylindrical tubes, 10 cm in diameter) penetrating about 30 cm deep into the sediments during a second cruise from 19 to 30 August 1988. Sediments consisted mainly of clay; results of a detailed granulometrical analysis are given by Jensen *et al.* (1991). Station data are shown in Table 1. Subsamples were immedi-

Contribution No. 111 from Sonderforschungsbereich 313 der Universität Kiel, Germany.

BODONEMATIDAE FAM. N. (NEMATODA, MONHYSTERIDA) ACCOMMODATING *BODONEMA VOSSI* GEN. ET SP. N. FROM THE DEEP-SEA BENTHOS OF THE NORWEGIAN SEA

PREBEN JENSEN

SARSIA



JENSEN, PREBEN 1991 07 10. Bodonematidae fam.n. (Nematoda, Monhysterida) accommodating *Bodonema vossi* gen. et sp. n. from the deep-sea benthos of the Norwegian Sea. - *Sarsia* 76:11-15. Bergen. ISSN 0036-4827.

The free-living nematode *Bodonema vossi* gen. n. et sp. n. is described based on adults and juveniles from the deep-sea benthos of the Norwegian Sea. *B. vossi* is unique by its differentiated pharynx into three regions consisting of: a tubular buccal cavity with sclerotized walls continuing into a long tubular portion with sclerotized walls and surrounded by a sheet of musculature, a mid-pharynx region with a series of bulbs each with sclerotized inner walls, a posterior region without sclerotized inner walls consisting of a narrow part and terminating with a pyriform bulb. The combination of these pharynx regions justify to establish a new family Bodonematidae with *Bodonema* as the type genus. Bodonematidae are placed in Monhysterida because the ovaries are outstretched; the presence of a progaster in *Bodonema* also indicates such a relationship. The equally long setae of second and third crown of cephalic sense organs suggest a relationship within Axonolaimoidea.

Preben Jensen, Marine Biological Laboratory, University of Copenhagen. Strandpromenaden 5, DK-3000 Helsingør, Denmark.

INTRODUCTION

Since 1986 several benthos samples were taken from the deep-sea benthos of the Norwegian Sea in order to examine regional and local relationships between sediments and fauna (cf. JENSEN 1988a; KÖSTER & al. in press, JENSEN & al. in press; ROMERO-WETZEL & GERLACH in press). More than 100 meio-benthic species were found and one of them turned out to be a new nematode which could not be included in one of the more than 500 nematode genera known. This species is described and its systematic position discussed.

MATERIAL AND METHODS

Benthos samples were collected with a USNEL box corer (50 cm × 50 cm) from R/V *Meteor* during the cruises 2.1 (19 June-2 July 1986) and 7.4 (17 August-4 September 1988) in the Norwegian Sea. Present specimens derive from two silty clay stations; i.e. Stn 61 (67°43' N, 05°55' E 1245 m, and Stn 70 (67°00' N, 07°46' E), 970 m. Extraction, concentration and fixation of material is outlined in JENSEN (1988b). The material is deposited in the nematode collection of the Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Federal Republic of Germany (NSIMB).

Contribution No. 114 from Sonderforschungsbereich 313 der Universität Kiel, Federal Republic of Germany.

DIAGNOSES

Bodonematidae fam. n.

Monhysterida, Axonolaimoidea. A characteristic pharynx differentiated into: a long, tubular anterior region with sclerotized walls and surrounded by musculature, a mid-pharynx region developed into bulbs with sclerotized inner walls, and a posterior region without sclerotized inner walls consisting of a narrow portion and terminally with a pyriform bulb. Gonads opposite and outstretched.

Type genus: *Bodonema* gen. n.

Etymology: Named after Dr Bodo von Bodungen, marine biologist at the Marine Research Institute, University of Kiel, FRG, chief-scientist and poet on *Meteor* cruise 7.4.

Bodonema gen. n.

Axonolaimoidea, Bodonematidae. Cephalic sense organs in three separate crowns with second and third crown of setae equally long. Copulatory apparatus with gubernacular apophyses and lateral differentiation. Ducts from caudal gland cells apparently atrofied, tail tip with subterminal dorsal outlet.

Type species: *Bodonema vossi* sp. n.

Etymology: Named after Dr Maren Voss, marine biologist in Sonderforschungsbereich 313 and member of the research team on *Meteor* cruise 7.4.

'AN ENTEROPNEUST'S NEST': RESULTS OF THE BURROWING TRAITS BY THE DEEP-SEA ACORN WORM *STEREOBALANUS CANADENSIS* (SPENGL)

PREBEN JENSEN

SARSIA



JENSEN, PREBEN 1992 09 10. 'An enteropneust's nest': results of the burrowing traits by the deep-sea acorn worm *Stereobalanus canadensis* (SPENGL). - *Sarsia* 77:125-129. Bergen. ISSN 0036-4827.

The burrowing enteropneust *Stereobalanus canadensis* occurs in abundances of 8-24 specimens per m² in the deep-sea benthos of the Norwegian Sea. Highest numbers are correlated with dense burrow systems where the sediment surface is slightly raised as a mound. A burrow system consists of several horizontal galleries of dichotomously branched burrows, 6 mm in diameter, down to c. 10 cm depth and connected with each other by vertical shafts. 'An enteropneust's nest' is introduced as a term denoting the aggregation of *S. canadensis* in such a burrow system below a mound resulting in considerable transport of particles and exchange of chemical constituents in the sediments. Faeces are deposited as small elongated pellets and in lots of up to 1300 in numbers in a burrow system. This suggests that the inhabitants of 'an enteropneust's nest' have a common faecal deposit.

Preben Jensen, Marine Biological Laboratory, University of Copenhagen, Strandpromenaden 5, DK-3000 Helsingør, Denmark.

INTRODUCTION

Only three deep-burrowing species weighing about 1 g or more wet weight and in abundances of less than 25 specimens per m² have up to now been found in the deep-sea benthos of the Norwegian Sea (ROMERO-WETZEL & GERLACH in press), i.e. the burrowing enteropneust *Stereobalanus canadensis*, the tube-living anthozoan *Cerianthus vogti* DANIELSEN (cf. JENSEN 1992) and an unidentified burrowing echiuran. ROMERO-WETZEL (1989) described the branched burrow system of *S. canadensis* and estimated the abundance of up to 16 specimens per m². The contents of brominated metabolites in *S. canadensis* and their negative effects on biological activity in its burrow wall lining were dealt with by JENSEN & al. (1992), and KÖSTER & al. (1991) dealt with exo-enzymatic activity and bacterial numbers in its gut, faecal pellets and burrow wall lining. As a continuation of these observations on ecological aspects of the natural history of *S. canadensis* this study focuses on the effects of the burrowing traits by this acorn worm.

MATERIAL AND METHODS

Thirty three samples with a modified USNEL box core sampler (50 × 50 cm), penetrating about 40 cm deep into the sediments, were taken at three stations on the Vøring Plateau, Norwegian Sea in July 1988. Twenty seven samples were from Stn 61 (67°43.1' N, 05°55.4' E; 1245 m depth), 2 samples from Stn 70 (66°59.9' N, 07°45.7' E; 970 m depth), and 4 samples from Stn 84 (67°41.9' N, 03°43.0' E; 1255 m depth); for station data: cf. JENSEN

(1988). Observation of burrows systems were obtained after removing one side wall of a box corer. Sediment was removed by gently washing the sediment with water (cf. Fig. 1A), by breaking pieces of sediment off by hand (cf. Fig. 1B), and with the aid of spoons and small spatulae. Several sediment sections were photographed and burrow systems depicted by pencil drawings in order to reconstruct the three-dimensional pattern of burrow systems. These simple methods optimized the sampling of fresh, undamaged animals and faecal pellets in the burrows as well as yielding a good estimation of burrow sizes, and precise sampling of burrow wall and adjacent sections of sediments. Innermost 0-1 mm and subsequent 1-2 mm wall sediment were scraped off by a 5 mm wide spatula to give samples of 2-10 ml. Control samples were taken with a 10 ml syringe which was pushed into sediment horizons 10-20 mm from the burrow walls. Samples for faunal analyses were fixed in 4 % formalin, stained with Bengal Rose, gently sieved on a 45 µm sieve, and sorted under a stereomicroscope. For scanning electron microscopy (SEM) samples from faecal pellets, and samples from surface and adjacent sediments were fixed in 4 % formalin, washed in distilled water, dehydrated and critical point dried (Balzer Union CPD 010). Samples were coated with 20 nm of gold using a Balzer Union SCD 004 sputterer, and examined on a Zeiss Nanolab 7 scanning electron microscope.

RESULTS

Two to six specimens of *Stereobalanus canadensis* were found in their burrows in each box corer (1/4 m²). The burrows are circular in cross section, 6 mm in diameter, and smooth. A burrow system consists of several horizontal galleries of dichotomously branched burrows down to 10 cm depth, connected with each other by vertical shafts; this

CERIANTHUS VOGTI DANIELSSEN, 1890 (ANTHOZOA: CERIANTHARIA). A SPECIES INHABITING AN EXTENDED TUBE SYSTEM DEEPLY BURIED IN DEEP-SEA SEDIMENTS OFF NORWAY

PREBEN JENSEN

SARSIA



JENSEN, PREBEN 1992 05 08. *Cerianthus vogti* DANIELSSEN, 1890 (Anthozoa: Ceriantharia). A species inhabiting an extended tube system deeply buried in deep-sea sediments off Norway. - *Sarsia* 77: 75-80. Bergen. ISSN 0036-4827.

Box core sampling, dredging and photographic records of sea floor structures at 1244-2926 m depth in the Norwegian Sea show the presence of the tube-dwelling anthozoan *Cerianthus vogti* DANIELSSEN, 1890 in an abundance of up to 3.5 specimens per m². This species has not been reported since the original description. *C. vogti* builds an extended, branched, horizontal tube system, probably several metres long, below the oxic-anoxic boundary layer. This tube system is considered to be a kind of 'gas pipeline' through which CH₄ and H₂S might accumulate and pass to supply chemoautolithotrophic bacteria living in body tissue as symbionts or in the tube itself, i.e. a bacterial gardening system. Through each of these two processes *C. vogti* may satisfy its food requirements in the oligotrophic deep-sea environment.

Preben Jensen, Marine Biological Laboratory, University of Copenhagen, Strandpromenaden 5, DK-3000 Helsingør, Denmark.

INTRODUCTION

Ceriantharians are known as tube-dwelling sea anemones. It is generally believed that they live in a vertical tube somewhat longer than the body itself (SCHÄFER 1962) or up to 1 m long (REMANE 1940). They occur from shallow waters to the deep-sea.

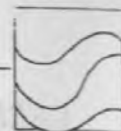
During a study of the biology of the enteropneust *Stereobalanus canadensis* in deep-sea sediments of Vøring Plateau, Norwegian Sea (KÖSTER & al. 1991; JENSEN, EMRICH & WEBER in press; JENSEN in press) several 40-cm deep box core samples contained a greenish-grey felt-like substance attached along the lower edges. Previously ROMERO-WETZEL (1989) suggested that this substance could derive from the tube of an echiuran worm. However, since an echiuran was found in its burrow (KÖSTER & al. 1991; own obs.) without any trace of a tube, the above suggestion can be abandoned. In the present study, three anthozoan specimens were found in such felt-like substances. The specimens belong to *Cerianthus vogti* DANIELSSEN, 1890, a species not reported since its original description from the Vøring Plateau, Norwegian Sea, when DANIELSSEN (1890) described two new *Cerianthus* species, *C. vogti* and *C. abyssorum*. The two species were considered synonymous by CARLGRÉN (1912) who selected *C. vogti* as the valid name.

By means of box core sampling and photographs of the sea floor from the deep-sea benthos of the

Norwegian Sea the abundance of *Cerianthus vogti* is estimated and an impression of the extension of its deeply buried tube system is given. A 'gas pipeline' hypothesis is finally presented where the tube system is suggested to accumulate and pass reduced compounds as supply for chemoautolithotrophic bacterial symbionts in its body tissues or as supply for a bacterial gardening system.

MATERIAL AND METHODS

Nine modified USNEL box core samples (50 × 50 cm), penetrating about 40 cm deep into the sediments, were taken in August 1988 at five stations between 1244 and 1393 m depth on the Vøring Plateau, Norwegian Sea (Table 1). The upper 10 cm of sediment consisted of brown silty-clay (cf. Fig. 1), with a water content of 50-70 %. The deep sediment horizon is grey with a water content less than 50 %. Observations on the location of tubes in the sediment were obtained after removing one side of a box corer. Sediment was removed by hand and by gently washing with water. Tubes were recognized by their greenish colour and by texture. The extension of each tube was recorded and photographs were taken of partly excavated tubes. One fresh specimen of *Cerianthus vogti* found within a tube was photographed. Two tentacles of this specimen were cut off and fixed in glutaraldehyde for an ultrastructural study of possible endosymbiotic bacteria; the remaining part of the body and all the tube fragments were fixed in 4 % formalin in sea water. Subsequent laboratory analyses of the preserved tubes revealed two additional specimens. Specimens were weighed after blotting on filter paper. The three specimens are deposited in the National Museum of Natural History, Leiden, The Netherlands.



Sedimentological and biological differences across a deep-sea ridge exposed to advection and accumulation of fine-grained particles

Sedimentology
Benthic ecology
Deep-sea ridge
Vøring Plateau
Norwegian Sea

Sédimentologie
Écologie benthique
Dorsale profonde
Plateau de Vøring
Mer de Norvège

Preben JENSEN ^a, Jan RUMOHR ^b and Gerhard GRAF ^b

^a Marine Biological Laboratory, University of Copenhagen, Strandpromenaden 5, DK-3000 Helsingør, Denmark.

^b Geomar Research Center for Marine Geosciences, University of Kiel, Wischhofstrasse 13, Kiel 14, FRG.

Received 7/02/91, in revised form 30/03/92, accepted 2/04/92.

ABSTRACT

Large amounts of clay and silt particles from the northern Vøring Plateau (Norwegian Sea) accumulate on a ridge (Vøring Plateau escarpment) situated at 1 245-1 310 m depth on the northern Vøring Plateau. Calculated Holocene sedimentation rates are up to 18 cm ky⁻¹, while amounting to less than 1 cm ky⁻¹ on the slope south of the ridge. Six stations were sampled - three on each side of the ridge - to obtain quantitative information of different biological components and relate these observations to the environmental conditions. Pronounced biological differences between the southern and northern sites are evident in terms of oxygen consumption, meio- and macrofauna composition, meiofauna biomass and meiofauna depth distribution. A specific fauna consisting of pogonophorans and nematode assemblages of relatively large-sized animals inhabits areas on Vøring Plateau which are characterized by high sedimentation rates and high organic carbon content. Accumulation of particles larger than 63 µm in sediment horizons between 6-10 cm depth is possibly due to vertical particle transports by a burrowing enteropneust.

Oceanologica Acta, 1992. 15, 3, 287-296.

RÉSUMÉ

Différences sédimentologiques et biologiques d'un côté à l'autre d'une dorsale profonde exposée à l'advection et à l'accumulation de fines particules

D'importantes quantités de particules argileuses et de vase en provenance du plateau continental de la Mer de Norvège se sont accumulées sur une dorsale, l'escarpement du plateau Vøring, à 1 245-1 310 m de profondeur. Les taux de sédimentation calculés pour l'Holocène y atteignent 18 cm par millénaire alors que, plus au sud, sur le talus continental, ils sont inférieurs à 1 cm par millénaire. Six stations ont été échantillonnées (trois de chaque côté de la dorsale) afin de quantifier les constituants biologiques et de comparer ces observations aux caractéristiques de l'environnement. Des différences notables entre les stations du nord et celles du sud sont observées dans la consommation de l'oxygène, dans la composition de la macrofaune et dans la composition, la biomasse et la répartition verticale de la méiofaune. Des populations de pogonophores et de nématodes, constituées d'ani-

Metabolic adaptations of deep-sea benthic foraminifera to seasonally varying food input

Peter Linke

Sonderforschungsbereich 313, Heinrich-Hecht-Platz 10, W-2300 Kiel 1, Germany

ABSTRACT: ATP content and metabolic activity of benthic foraminifera were determined from deep-sea sediments of the Norwegian-Greenland Sea. Metabolic activity was analysed by measurements of Electron Transport System (ETS) activity and heat production. This, combined with live observations, revealed 2 survival strategies. *Rupertina stabilis*, an obligate suspension feeder, is adapted to conditions in which it receives a steady input of particles throughout the year, enabling it to maintain a relatively high ATP content (153 ± 23 ng ATP ind.⁻¹) with a reduced ATP turnover rate (0.008 s⁻¹). In contrast *Cibicides lobatulus*, *Pyrgo rotalaria* and *Rhabdammina abyssorum* undergo large (up to 10-fold) fluctuations in seasonal values of ATP and heat production, but retain a high, relatively constant ATP turnover rate (i.e. seconds). Such a rapid turnover allows these foraminifera to take quick advantage of sudden nutrient inputs; this state of readiness, however, is maintained at the cost of the protoplasm, which benthic foraminifera are apparently capable of metabolizing in times of starvation. *C. lobatulus* and *P. rotalaria* responded to several sedimentation events with an increase in ETS activity; single cells sometimes showed extremely high ATP values (50- to 100-fold increase), reflecting an individual physiological response to food input to the deep-sea.

INTRODUCTION

The abundance of benthic foraminifera in the deep-sea is reported to be greater than that of any other eukaryotic taxon (Tietjen 1971, Hessler 1974, Smith et al. 1976, Tendal & Hessler 1977, Snider et al. 1984, Gooday 1986, 1990, Alongi & Pichon 1988, Altenbach & Sarnthein 1989, Gage & Tyler 1991). In the deep-sea of the Arctic oceans they account for a major part of the benthic biomass (Fetter 1973, Basov & Khusid 1983). New techniques are already being used to measure the biomass of benthic foraminifera directly by organic carbon (Altenbach 1987) and adenosine-5'-triphosphate (ATP) assays (DeLaca 1986). Little information, however, is available on their metabolism. Since protozoa have a high growth potential they may be expected to be of importance in terms of turnover rates in biotopes where they are especially abundant.

The Norwegian-Greenland Sea is influenced by different currents and water masses, varying processes which may be expected to control particle sedimentation. The Norwegian Atlantic Current imports warm

Atlantic water; on the Norwegian Shelf the Norwegian Coastal Current flows with less saline water to the Northeast; the East Greenland Current brings in a cold water mass from the Arctic (Fig. 1). Mackensen and co-authors (1985) conducted the first large-scale studies on foraminiferal distribution patterns in the Norwegian-Greenland Sea and concluded that the oxygen content of the bottom water and the organic carbon load of the sediment are among the environmental parameters that influence foraminiferal assemblages. The following investigations were guided by the growing realization that adaptation to nutritional conditions rather than water mass properties or physical parameters alone controls foraminiferal distribution (Altenbach 1985, Lutze et al. 1986, Mackensen 1987, Linke 1989, Lutze & Thiel 1989, Thies 1991, Gooday et al. 1992).

It is already evident that the response by a bathyal benthic community to a pulse of natural organic matter occurs within days (Graf 1989). A direct response of shallow-water benthic foraminifera to food input has been documented in the Kiel Bight, Baltic Sea

Microhabitat preferences of benthic foraminifera—a static concept or a dynamic adaptation to optimize food acquisition?

P. Linke^a and G.F. Lutz^b

^aSonderforschungsbereich (SFB) 313, Olshausenstraße 40–60, Kiel University, 2300 Kiel, Germany

^bGeologisch-Paläontologisches Institut, Olshausenstraße 40–60, Kiel University, 2300 Kiel, Germany

(Received February 20, 1992; revision accepted August 15, 1992)

ABSTRACT

Linke, P. and Lutz, G.F., 1993. Microhabitat preferences of benthic foraminifera—a static concept or a dynamic adaptation to optimize food acquisition? In: M.R. Langer (Editor), *Foraminiferal Microhabitats*. *Mar. Micropaleontol.*, 20: 215–234.

In situ observations of microhabitat preferences of living benthic foraminifera are presented from sediments of the Norwegian–Greenland Sea, the upwelling area off northwestern Africa and the shallow-water Kiel Bight (Baltic Sea). Certain foraminiferal species (e.g. *Cibicides wuellerstorfi* and *Rupertina stabilis*) can be regarded as strictly epibenthic species, colonizing elevated habitats that are strongly affected by bottom water hydrodynamics. Large epibenthic foraminifera (e.g. *Rhabdammina abyssorum* and *Hyperammina crassatina*) colonize the sediment surface in areas where strong bottom currents occur and might have by virtue of their own size an impact on the small-scale circulation patterns of the bottom water. Motile species changing from epifaunal to infaunal habitats (e.g. *Pyrgo rotalaria*, *Melonis barleeanum*, *Elphidium excavatum clavatum*, *Elphidium incertum*, *Ammotium cassis* and *Sphaeroidina bulloides*) are regarded here as highly adaptable to changes in food availability and/or changing environmental conditions. This flexible behaviour is regarded as a dynamic adaptation to optimize food acquisition, rather than a static concept leading to habitat classification of these ubiquitous rhizopods.

Introduction

Benthic foraminifera have been reported from virtually all marine environments indicating a broad ecological adaptability. In oxygenated deep-sea sediments, foraminifera occupy epifaunal and shallow (0–2 cm) or deep (>2 cm) infaunal microhabitats (Corliss, 1985; Gooday, 1986; Altenbach and Sarnthien, 1989; Mackensen and Douglas, 1989; Thies, 1990). Some taxa which live infaunally in well-oxygenated sediments also occur near the sediment surface in dysaerobic environ-

ments suggesting that an ability to tolerate low oxygen concentrations allows these species to survive within the sediment (Mackensen and Douglas, 1989). Some epifaunal species live attached to firm substrates which elevate them above the sediment surface. At bathyal depths stones and biogenic structures offer suitable and readily available attachment surfaces (Lutze and Altenbach, 1988; Lutze and Thiel, 1989; Mackensen and Douglas, 1989; Gooday et al., 1992b). In the Norwegian–Greenland Sea the miliolid *Miliolinella subrotunda* achieves elevation by perching on top of a self-constructed agglutinated tube that may be up to 6 mm long (Altenbach et al., 1992, this volume). Encrusting foraminifera also occur on surfaces close to hydrothermal vents (Van

Correspondence to: P. Linke, Kiel University, Sonderforschungsbereich (SFB) 313, Olshausenstraße 40–60, 2300 Kiel, Germany.

Geol. Jb.	A 128	251—265	1 Abb.	2 Taf.	Hannover 1991
-----------	-------	---------	--------	--------	---------------

Technik und Signifikanz der Lebendfärbung benthischer Foraminiferen mit Bengalrot

GERHARD F. LUTZE & ALEXANDER ALTENBACH

Foraminifera, lebendes Taxon, Präparation, Färbung, Gehäuse, Artengemeinschaft

Kurzfassung: Die von WALTON (1952) beschriebene Anfärbung lebender Foraminiferen mit dem Farbstoff Bengalrot (engl. Rose Bengal, C. I. 45440) hat inzwischen verschiedene methodische Verbesserungen erfahren und liefert bei Reihenauswertungen ein zuverlässiges Kriterium zur Unterscheidung leerer und plasmagefüllter Gehäuse benthischer Foraminiferen. Durch die Mikromengenbestimmung von organischem Kohlenstoff kann erstmals quantitativ nachgewiesen werden, daß bei sorgfältiger Bearbeitung und der Einhaltung gewisser Arbeitsmethoden mehr als 96% der Ansprachen exakt erfolgen. Zusammen mit den restlichen Bruchteilen, die zumindest zum Teil auf stark ausgezehnten, von Parasiten befallenen oder gerade abgestorbenen Individuen beruhen, wird ein sicheres und reales Abbild der lebenden Artengemeinschaften geliefert.

[Technique for Staining Living Benthic Foraminifera with Rose Bengal]

Abstract: The technique for staining living benthic foraminifera with Rose Bengal, described by WALTON (1952), has since undergone some improvements that now provide reliable criteria for systematic distinctions between empty and plasma-filled tests. Micro-analyses of organic carbon can verify quantitatively that careful work, when done in strict compliance with certain procedures, leads to over 96% correct identifications. Including the remaining uncertainties, at least partially due to specimens that have been essentially starving, suffer from parasites or presently died, a realistic picture of the vivid community is provided.

INTERNATIONAL WORKSHOP ON ARCTIC POLYNYAS

11-13 January 1993

Seattle, Washington, USA

Abundances and Distribution Patterns of the Epibenthic Fauna in the Northeast Water (NEW)

Dieter Piepenburg
Institute for Polar Ecology
University of Kiel
Wischhofstrasse 1-3 (Geb.12)
D-2300 Kiel 14
Germany

Abstract

The epibenthic fauna in the polar waters off Northeast Greenland was investigated in 1985 and 1990 by trawl catches and sea floor imaging. Echinoderms were dominant faunal elements in the samples. Distribution and composition of the various species assemblages are supposed to be related to sea floor properties and patterns in current regime, sea ice cover, pelagic and sympagic production, and sedimentation. The basic results of the present study lead to the following hypotheses to be tested by future investigations:

(1) There is evidence that the Northeast Water (NEW), a shelf polynya off Northeast Greenland, has a key influence on the distribution, abundance and composition of the benthos. Locally high abundances of brittle stars on the shelf banks are thought to be sustained by a pelagic and/or sympagic production which is relatively high in the polynya and from which a large proportion is partitioned to the benthal.

(2) A convergent anti-cyclonic gyre with its centre over the Belgica Bank may act as a retention mechanism and probably leads to an accumulation of organic particles and meroplanktonic larvae, thus favouring (a) the sedimentation and flux of food to the benthos, and (b) the survival and spatfall of meroplanktonic larvae.

Abundance, biomass and small-scale dispersion pattern of brittle stars (Echinodermata: Ophiuroidea) on the Kolbeinsey Ridge north of Iceland

Dieter Piepenburg, Karen v. Juterzenka

Institut für Polarökologie, Universität Kiel, Wischhofstraße 1-3
(Geb.12), D-2300 Kiel 14, Germany

Summary

Species composition, abundance, biomass and spatial distribution pattern of brittle star assemblages of the Kolbeinsey Ridge, north of Iceland, were investigated by analysing seafloor photographs and epibenthic sled catches. Sampling was conducted in July 1992 along a 34km-wide cross-ridge transect at 67°55'N in depths ranging from 500 to 1100m. The analyses were part of a multidisciplinary meso-scale field study on benthic community structures and particle flux carried out in the framework of the "Sonderforschungsbereich 313" of the University of Kiel. The analyses of exposures and samples indicated the existence of an ecological cross-ridge gradient.

The ridge top was inhabited by a typical hard-bottom fauna dominated by sessile suspension-feeders. Bottom morphology and community properties appeared to be controlled by strong bottom currents. Both ridge slopes were characterized by soft bottom habitats. However, there is evidence from photographs as well as from trawl catches that the epibenthic megafauna (ophiuroids like *Ophioscolex glacialis* and *Ophiopleura borealis* as well as large crinoids and asteroids) is more abundant at the western slope. The by far most abundant brittle star species was *Ophiosten gracilis* occurring in densities up to 753 ind.m⁻². These findings may indicate differences between the slopes in terms of bottom current regimes and, hence, patterns of lateral particle advection.

A total of 5 brittle star species were found at the 5 stations. Generally, ophiuroid densities were significantly larger on the eastern slope. Biomass of *Ophiosten gracilis* extrapolated from photographically determined abundances reached up to 120.2 mg m⁻².

A program for computer-aided analyses of ecological field data

Dieter Piepenburg and Uwe Piatkowski¹

Abstract

A program for IBM-compatible microcomputers is introduced which combines several complementary analyses of species-station-tables generated in ecological field investigations. The scope of the program encompasses table editing functions, routines for community delimitation by cluster analysis and procedures for the analysis of properties related both to stations (e.g. diversities) and species (e.g. abundance statistics and association indices). The essential reasoning behind the application of community studies is presented briefly, as well as the multi-step analytical approach implemented in the program.

Introduction

One main objective in ecological field studies is the delimitation of species assemblages and/or faunistic zones, and the description of their spatial (and/or temporal) distribution and composition. These investigations, widely known as community analyses, are often based on extensive species-station-tables, i.e. data arrays typically in the form of abundance measures of the various species represented in a series of stations or collections. Based on experience in studying marine zooplankton and benthos communities (Piepenburg, 1988; Piatkowski, 1989) a computer program was developed to assist in performing analyses of species-station-tables.

The conceptual basis of species-station-table analyses is the 'community' of co-occurring species. This concept is one of the most important rationales of ecological research (Odum, 1973), but there are various definitions reflecting different theoretical approaches (see Gray, 1981). The definition also applied in the present paper was formulated by Mills (1969): 'Community means a group of organisms occurring in a particular environment, presumably interacting with each other and with the environment, and separable by means of ecological survey from other groups.' This pragmatic approach is based on methodology and avoids an ecological interpretation which may be controversial (see Petersen, 1989). The differences of the various theories refer mainly to the degree of integration of communities and the role of the biological self-regulation of community structures, i.e. the question whether the spatial

distribution of species is mainly influenced by biological interactions or rather by abiotic gradients (Gray, 1981).

Following a multi-step strategy for the study of multi-species distribution patterns (see Bølter *et al.*, 1980; Field *et al.*, 1982), which encompasses a suite of multivariate and analytical techniques, quite a number of computations are usually involved (Legendre and Legendre, 1987). For computer-aided analyses a variety of spreadsheet and statistical software is available, each offering a subset of the tools necessary to perform the various tasks, such as table editing, data handling, differentiation of intrinsic data fractions by cluster analyses, and computation of station-specific and species-specific parameters. A computer program, however, which combines the whole suite of these procedures is harder to find. Here, we introduce a comprehensive computer program, integrating the different parts of a multi-species data analyses, in order to conduct this often time-consuming work in a quick and safe way.

Analytical approach

Ecological field investigations usually result in complex sets of biotic (and/or environmental) data from which patterns or relationships are to be extracted. For instance, community studies are based on a faunistic inventory in a well-defined area by collecting or observing organisms at several stations, i.e. at certain locations and/or at certain time intervals. The methodological rationale of the analysis of the resulting species-station-table may be stated as follows: the distribution of the various species represented in a series of stations is not random, but displays a certain pattern, i.e. certain species groups (assemblages) are limited or at least concentrated in their occurrence to certain station groups (faunistic zones). This 'multispecies distribution pattern' is discernible from species-station-tables by multivariate analytical techniques. Field *et al.* (1982) have provided an overall strategy for the analyses of multispecies data sets. Most of its various stages can be performed by the program introduced in the present paper.

Classification techniques are methods to extract patterns from complex data sets, e.g. to delimitate station groups and species assemblages from species-station-tables and to discern their resemblance structure. They are not the end of a community study but rather the starting point for further data analyses and ecological interpretations. The 'intrinsic' structures of communities may be described, for instance, by certain station-specific and species-specific properties (e.g. diversities and

¹Institut für Polarökologie der Universität Kiel, Olshausenstrasse 40 and ²Institut für Meereskunde an der Universität Kiel, Düsternbrooker Weg 20, W-2300 Kiel, Germany

Effects of sediment resuspension and turbulence on bacterial activity

W. Ritzrau*, J.W. Deming

University of Washington WB - 10, School of Oceanography, Seattle WA 98195, U.S.A.

* present address: SFB 313, Universität Kiel, Heinrich Hecht Platz 10, 2300 Kiel, F.R.G.

Abstract

The abundance and biomass of bacteria in bottom waters is known to increase upon sediment resuspension. Whether this is due to passive introduction of many and larger bacteria from the seabed or to metabolic stimulation of the resuspended sediment (or existing pelagic) bacteria is not known. To better understand the resuspension effects on the sediment bacteria, we resuspended intertidal sediments into sterile pre-filtered (0.2 μ m) natural seawater and into an artificial sea-salt solution, subsequently and measuring comparative rates of ¹⁴C- and ³H-amino acid utilization in agitated versus still samples over a 36-h period at 13°C. Under the nutrient conditions of natural seawater, agitation significantly stimulated amino acid utilization, almost doubling the measured rates on a per cell basis (both tracers). Under more limiting nutrient conditions, the agitation effect, in general was more pronounced, with a tripling of the rate in one case. After considering substrate collector efficiencies under different conditions examined, we attribute the turbulence - stimulated bacterial activity in our samples to a combination of : 1) increased activity of bacteria resuspended a free-living cells. due to increased encounter of nutrient hot spots in the agitated samples; 2) increased activity of resuspended bacteria attached to particles, due to relief of diffusion limitation on substrate delivery to the cell by turbulence. The stronger stimulatory effects, observed in a low-nutrient regime indicate the importance of determining kinetic parameters for bacteria in oligotrophic environments.

Particle properties and microbial transformation in the North East Water Polynia; preliminary results.

W. Ritzrau[§], J.W. Deming^{*}, E. Bauerfeind[†]

[§] SFB 313, A3, [†] SFB 313, A1

^{*} University of Washington, WB-10, Seattle, WA 98195

In July and August 1992 an American science party with German participation visited the North East Water Polynia off the northeastern coast of Greenland. The NEWP is the largest, coldest and most northerly of the summer polynyas in the Arctic environment. Previous investigations revealed high primary productivity within in the polynia supporting a general biological richness.

Preliminary results on total suspended matter, particulate organic carbon and nitrogen as well as bacterial abundance, size distribution and activity in the water column at selected stations in the NEWP are presented. Spatial heterogeneity of microbial activity was found to be dependent on the ice-conditions. Vertical gradients appear to be governed hydrographical setting of polar vs. Arctic intermediate water masses.

Poster: International Workshop on Arctic Polynyas. Seattle, Washington, U.S.A. January 11-13, 1993.

GEOMAR
Wischhofstrasse 1-3
2300 Kiel 14, Germany

Limnol. Oceanogr., 37(5), 1992, 1081-1086
© 1992, by the American Society of Limnology and Oceanography, Inc.

Increase of microbial biomass in the benthic turbidity zone of Kiel Bight after resuspension by a storm event

Abstract—Near-bottom water samples were collected at 7, 12, 20, 40, and 300 cm above the seabed in situ at two stations in Kiel Bight during calm hydrographic conditions and during a storm-induced subsequent resuspension event in fall 1989. Measurements of seston, particulate organic C, particulate organic N, and microbial biomass revealed storm-related differences in the composition of the particulate matter in the benthic turbidity zone restricted to a height of ~40 cm above the seabed at both sites. At the offshore site seston levels during the storm were about twice as high as during calm conditions (signed-rank $P \leq 0.005$). Increased bacterial numbers and enlarged median cell sizes during the storm resulted in significant (α , 0.069–0.01) increases in bacterial biomass to a height of ~20 cm above the seabed. Therefore, stimulation of microbial growth by resuspension can provide an additional energy source to the benthic community.

Both benthic and pelagic microbial biomass can contribute energetic support to the benthic heterotrophic community of higher organisms (Loo and Rosenberg 1989). This support is most significant at aphotic depths in the oceans and at shallow depths during winter when the input of pelagic primary production to the benthos is minimal. In these shallow areas, the effects of atmospheric storms during autumn, winter, and spring can penetrate to a water depth of well over 17 m causing resuspension of particles at the sediment–water interface in the benthic turbidity zone (BTZ; Rhoads et al. 1984). This resuspension not only passively increases bacterial abundances near the seabed but also appears to stimulate bacterial growth there (Wainwright 1987, 1990). Thus, due to large bacteria known to inhabit aggregates generated at the sediment–water

interface (Rhoads et al. 1984) or to stimulated growth (cell enlargement) upon resuspension, the size distribution of bacteria in near-bed waters of the BTZ can be expected to shift to larger forms. Within a few hours of particle resuspension both physico-chemical processes and microbial activity further enhance aggregate formation (Muschenheim 1987). The predictable result of all of these processes is to increase the amount of particulate organic material available for suspension feeders in the near-bed water mass.

Muschenheim et al. (1989) described gradients of particle quantity and quality in a water layer 10 cm above the sediment. Their findings, as well as those of Wainwright (1987, 1990) were based on flume experiments. This note reports in situ gradients of total suspended matter (seston), particulate organic C (POC), particulate organic N (PON), and microbial biomass in a water layer 7–300 cm above the sediment at a station in Kiel Bight. A comparison is made between the common autumn hydrography of a stratified water column and an unusually intense storm to demonstrate the effects of wind-induced resuspension on these parameters.

During two cruises aboard the RV *Littorina* on 21 November and 12 December 1989, near-bottom water samples were taken at station "Gabelsflach" 8.4 km offshore (54°33,30'N 10°05,70'E) and at nearshore station "Boknis-Eck" 2.1 km offshore (54°32,33'N 10°03,05'E) in Kiel Bight with a modified near-bottom water sampler (Fig. 1) described by Eversberg (1990). This device allows for collection of distinct water samples at variable heights above the seabed (in this study at 7, 12, 20, and 40 cm). Use of a redesigned, four-footed frame with centered sampling snorkels reduces hydrodynamic artifacts in the area of sampling; virtually undisturbed near-bottom water reaches the water inlets at the ends of the

Acknowledgments

We are grateful to P. Kemp and an unknown reviewer for their detailed suggestions. We especially thank J. W. Deming for helpful discussion, editorial comments, and partial support during manuscript revision as well as P. A. Jumars for advice on statistical analyses.

Abundance, biomass, size-distribution and bioturbation potential of deep-sea macrozoobenthos on the Vøring Plateau (1200–1500 m, Norwegian Sea)¹

MARINA B. ROMERO-WETZEL and SEBASTIAN A. GERLACH

Institut für Meereskunde, Kiel, FRG

MS. received 4. 7. 1990
MS. accepted 23. 4. 1991

Abstract

17 box corer samples were collected at a water depth of 1200–1500 m on the Vøring Plateau (about 67°–68° N; 03°–08° E). Sediment was sieved through 0.5 mm meshes and analysed for macrozoobenthos and its burrows. Taxa which were present in more than 50 % of the samples included the bivalve *Malletia obtusa*, polychaets (*Paramphipome jeffreysii*, *Aricidea abbranchiata*, *Chaetozone setosa*, *Notomastus latericeus*, *Myriochele* sp. and *M. fragilis*), the sipunculid *Golfingia* (*Nephasoma*) sp., the ophiurid *Ophiocten gracilis* and the enteropneust *Stereobalanus canadensis*. Other macrozoobenthic species were not present in sufficient abundance to be sampled in significant numbers within the 17 samples (each mostly 0.125 m²) covering a total of 2.3 m².

Notomastus latericeus and *Paramphipome jeffreysii* penetrate 10 cm into the sediment, and a *Golfingia* sp. lives in vertical burrows which extend deeper than 20 cm. *Stereobalanus canadensis* builds horizontal galleries 6–10 cm into the sediment. The Anthozoa *Cerianthus vogti* and unidentified Echiurida live in large deeper burrows.

Using additional data from the literature, a log size spectrum was constructed starting with species of 0.01 to 100 µg wet body mass (meiofauna), which runs up to very large macrozoobenthic species such like *Stereobalanus canadensis* (up to 1.5 g), *Cerianthus vogti* (3 g) and unidentified Echiurida (15 g wet body mass). Though these 3 very large endofauna taxa occur with a total abundance of only about 4 ind./m², their biomass (wet weight) can tentatively be estimated to be in the order of 7 g/m². This represents 70 % of the total macrofauna biomass (about 10 g wet weight/m²). 96 ind./m² of "larger macrofauna" (10 mg to 1 g wet body mass) represent a biomass of 2.5 g/m². 514 ind./m² of "small macrofauna" (0.1–10 mg wet body mass) represent a biomass of 0.78 g/m². 110 000 ind./m² of "large meiofauna" (1–100 µg wet body mass) represent 0.89 g/m². The importance of biomass relationships for bioturbation and for deep-sea benthic metabolism is discussed.

Kurzfassung

Abundanz, Biomasse, Größenverteilung und Bioturbations-Potential des Tiefsee-Makrozoobenthos auf dem Vøring-Plateau (1200–1500 m, Norwegische See)

17 Großkastengreifer-Proben wurden in 1200–1500 m Wassertiefe auf dem Vøring Plateau (etwa 67°–68° N; 03°–08° E) genommen. Das Sediment wurde durch 0,5 mm-Maschen gesiebt, das Makrozoobenthos analysiert. Taxa, die in mehr als 50 % der Proben vorkommen, sind: die Muschel *Malletia obtusa*, die Polychaeten *Paramphipome jeffreysii*, *Aricidea abbranchiata*, *Chaetozone setosa*, *Notomastus latericeus*, *Myriochele* sp. und *M. fragilis*, der Sipunculide *Golfingia* (*Nephasoma*) sp., der Schlangensterne *Ophiocten gracilis* und der Enteropneust *Stereobalanus canadensis*. Die übrigen Makrofauna-Arten waren nicht häufig genug, als daß man ihre Verbreitung signifikant mit 17 Proben von in der Regel 0,125 m² (2,3 m²) hätte erfassen können.

Notomastus latericeus und *Paramphipome jeffreysii* dringen 10 cm tief in das Sediment ein. *Golfingia* sp. lebt in vertikalen Bauten, welche tiefer als 20 cm nach unten reichen. In 6–10 cm Sediment-Tiefe baut *Stereobalanus canadensis* horizontale Galerien. In weiten tieferen Gängen leben Anthozoa (*Cerianthus vogti*) und nicht näher identifizierte Echiurida.

Unter Verwendung zusätzlicher Daten von anderen Autoren wird ein logarithmisches Größen-spektrum konstruiert, welches bei 0.01–100 µg Feuchtgewicht-Körpermasse beginnt (Meiofauna) und

¹ Publication No. 90 from Sonderforschungsbereich 313 "Sedimentation im Europäischen Nordmeer" of Kiel University. The research has been financed by Deutsche Forschungsgemeinschaft.

CHONDROCLADIA GIGANTEA (DEMOSPONGIAE) -
THE GIANT CLUBSPONGE OF THE NORTHEAST ATLANTIC

Chondrocladia gigantea is a most remarkable stalked sponge living on soft bottoms and attaining a height of 60 cm or more (Fig. 1). An elaborate branched "root"-system can reach 20 cm down into the bottom, anchoring the club-shaped sponge body, which is supported by a thick, spirally twisted stem of fibers of siliceous spicules and spongine. The surface of the sponge is velvetlike, light pink in life and has numerous longer or shorter papillae with spherical distal ends.

C. gigantea was first found by "The Norwegian North-Atlantic Expedition" (1876-1878) and described by Hansen (1885). Taken again by The Danish Ingolf Expedition 1895-96 and the Norwegian Michael Sars Expedition 1902, it was redescribed by Lundbeck (1905). Later, published and unpublished records have added substantially to the knowledge of its geographic and bathymetric distribution (Figs. 2, 3).

Most records are from the southern part of the Norwegian Sea and the Iceland Sea (the area between the island of Jan Mayen and Iceland), on the northern flank of the ridge from Scotland to Greenland. A single record south of the ridge, at 1960 m, is uncertain (Lundbeck 1905). Another well documented area is the Davis Strait and Baffin Bay (Brøndsted 1933). If it turns out that *C. gigantea* and *C. grandis* Verrill, 1879 are synonyms, a third area is off Nova Scotia. Three records are outside the mentioned areas; one is between Greenland and Svalbard (Koltun 1964), and two are in the Northwest Pacific, off Sakhalin and the Kuriles (Koltun 1958).

Koltun (1958, 1959) gave the bathymetric distribution as 238-615 m and 1450-2127 m. Because the 1450 m depth in the station list seems to be given as "970-1450 m" (Koltun 1964), his opinion about the distribution gap is not clear. The two Pacific records seem to have come from 200-400 m depth. In the deep interval four records are known of which the two deepest must be considered uncertain so far. One is referred to above (Lundbeck 1905, 1960 m), and the other is a small fragment from off the Norwegian coast (Hansen 1885, 2127 m). In the collections of the Zoological Museum, University of Copenhagen, there is a perfect specimen from 1600 m off West Greenland, and the fragmentary specimen taken deepest off Iceland originates from "860-1200 m". Our present records thus place the reliably known bathymetric distribution of *C. gigantea* from 240 to 1600 m, with the main occurrence between 500 and 1000 meters.

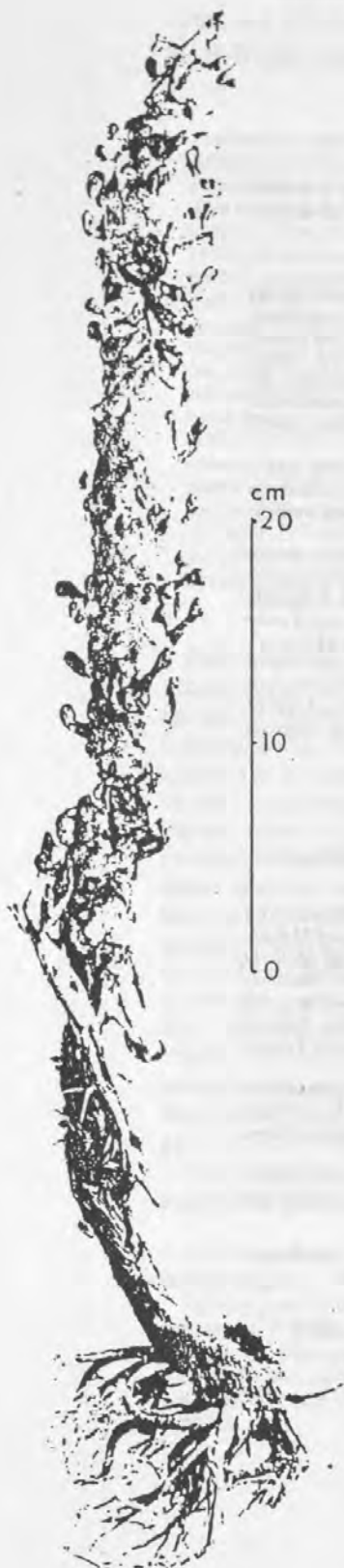


Fig. 1. *Chondrocladia gigantea* from 893 m depth, north of Iceland. The largest specimen ever recorded. BIOICE St. 2083. July 4, 1992.

The temperature range for the species, according to Koltun (1959), is $+0.66 - +2.7^{\circ}\text{C}$. However, these are the temperatures for the two Pacific records, and Koltun may have overlooked that Lundbeck (1905) concluded the main occurrence of *C. gigantea* to be in water of negative temperature, a matter further supported by the information given by Brøndsted (1933). All old and new records deeper than 500 m are from water of negative temperature ($-1.1^{\circ} - -0.3^{\circ}\text{C}$), except for the dubious one at 1960 m (3.1°C).

The shallowest record from West Greenland is at about 300 m depth with about 2°C , and another one is at 490 m with $+0.7^{\circ}\text{C}$. Off East Greenland there is one record at about 240 m at $0-1^{\circ}\text{C}$. North of Iceland the shallowest record is at 285 m with about 2°C , and on the top of the Iceland-Faroes Ridge there is one at 490 m with 2.5°C . The shallowest record from the Norwegian coast is at 669 m and -0.5°C . Thus, it seems possible that the upper distribution limit of *C. gigantea* is determined by temperatures of $2-3^{\circ}\text{C}$, the species accordingly occurring at shallower depths in West Greenland than off the Norwegian coast under the warm North Atlantic Current.

The lower distribution limit has another explanation than temperature. Judged from the distribution patterns (Fig. 2) it seems that at depths greater than about 1500 m the ecological niche occupied by a stalked, large,

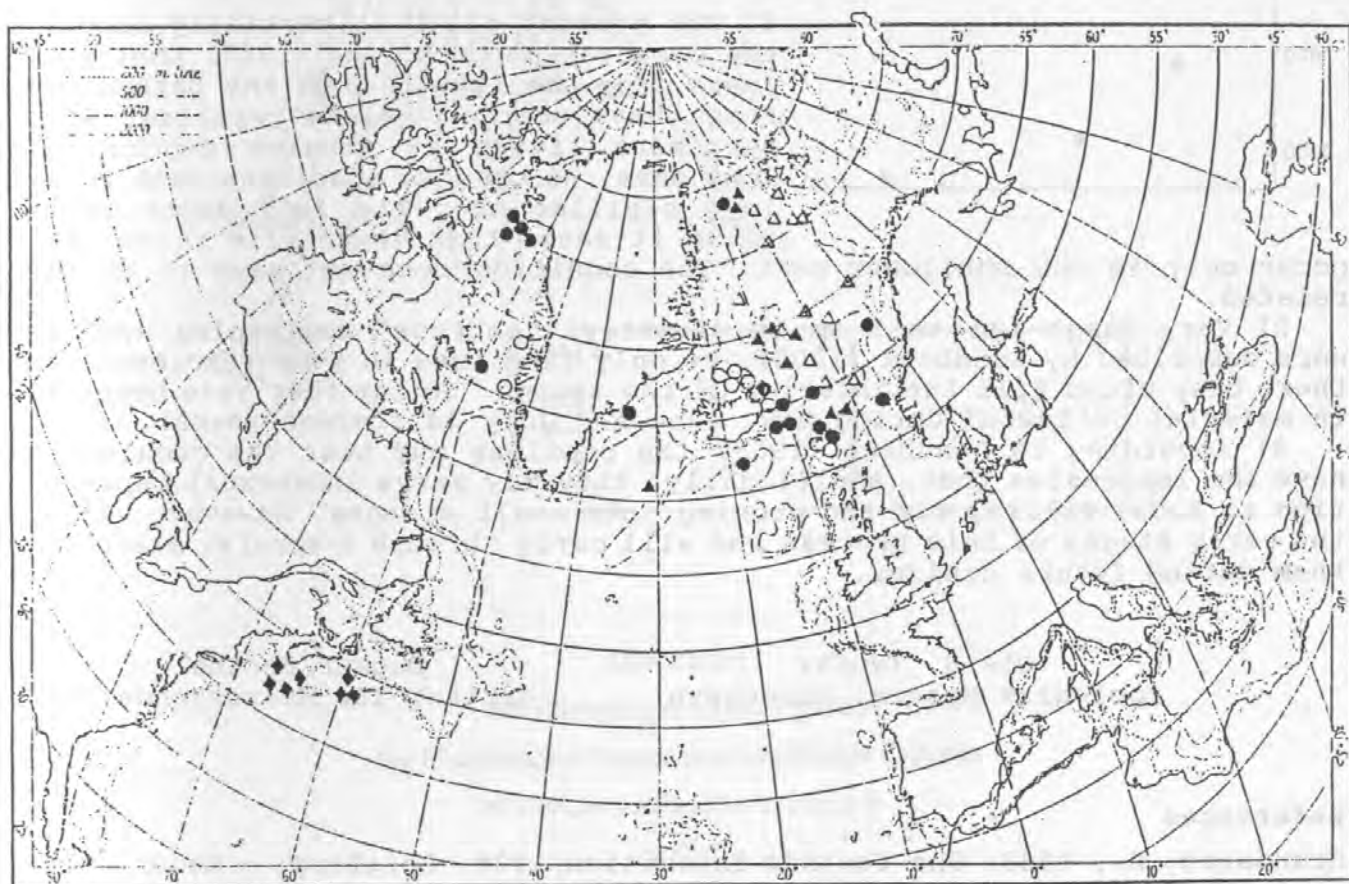


Fig. 2. The distribution of *Chondrocladia gigantea* and *Caulophacus arctica*. Records are published by U.S. Comm. Fish. Fisheries (1882), Hansen (1885), Fristedt (1887), Lundbeck (1905), Topsent (1913), Burton (1928), Brøndsted (1933) and Koltun (1959, 1964, 1967). Unpublished records are from the Tjalfe Expedition 1908-1909, the NORBI Expedition 1975, the "Meteor" Cruise 13 (SFB 313) and cruises with the Faroese "Magnus Heinason" and the Norwegian "Håkon Mosby" around the Faroes and Iceland. Open symbols are unpublished records. Filled symbols are published records.

● *Chondrocladia gigantea* ◆ *Chondrocladia grandis* ▲ *Caulophacus arcticus*

flat-bottom sponge in the Greenland and Norwegian Seas is taken over by the hexactinellid sponge *Caulophacus arcticus* (Hansen, 1885). This species attains stem lengths of more than 25 cm, and the body can be at least 15 cm in diameter, with the form of a mushroom, although with a somewhat folded edge. It lives at temperatures of -1.1 to $+0.4^{\circ}\text{C}$ (in a single case at 2.4°C), at 1450-4379 m (Koltun 1967). The change may be related to the lower sedimentation and food availability at great depths.

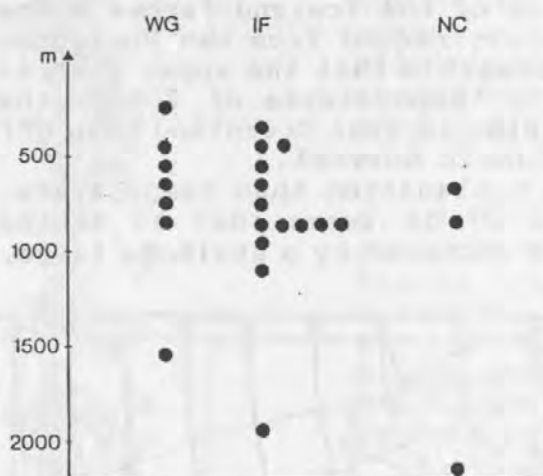


Fig. 3. The depth distribution of the records of *Chondrocladia gigantea* off West Greenland (WG), Iceland & the Faroes (IF) and the Norwegian coast (NC).

A number of problems concerning the morphology and biology of *C. gigantea* are tackled now as more material is collected during the ongoing BIOFAR and BIOICE programmes around the Faroes and Iceland:

1) Our present material partially supports the observation of Koltun (1959) that specimens from the lower end of the bathymetric range have short knoblike papillae, while specimens living at greater depths have long ones. We observe specimens with rather long papillae over the full depth range, while it seems that those with short ones

occur only in the shallower part. The condition does not seem to be size related.

2) Very large (up to 5 mm in diameter) "embryos" containing spicules were described by Lundbeck (1905). We only find them in some specimens, but there they often fill the interior of the sponge. So far they have been seen in material collected during May, June and July (different years).

3) According to Lundbeck (1905) the papillae may bear the oscules. We have the impression that, additionally, they may serve in asexual reproduction as buds, falling off and growing into small sponges. However, we lack the early stages of this process and will carry through a special search for them during future cruises.

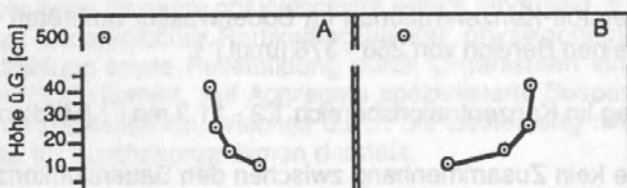
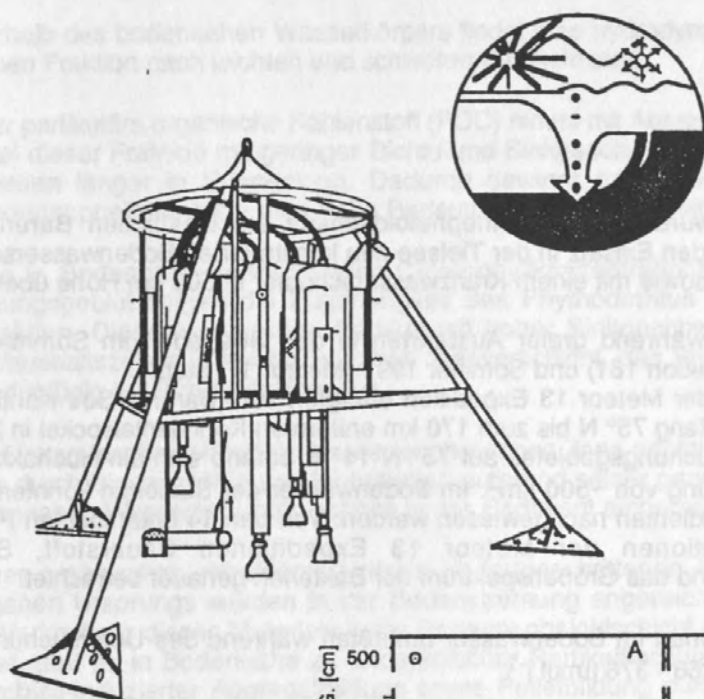
Ole S. Tendal
Zoologisk Museum, København

Dagmar Barthel
Institut für Meereskunde, Kiel

References

- Brøndsted, H., 1933: The *Godthåb* Expedition 1928. Porifera. - Meddr. Grønland 79 (5): 1-25.
- Burton, M., 1928: Hexactinellida. - Dan. Ingolf-Exped. VI, 4: 1-18.
- Fristedt, K., 1887: Sponges from the Atlantic and Arctic oceans and the Bering Sea. - Vega Expeditionens Vetensk. Iagttagelser IV: 401-471.
- Hansen, G.A., 1885: Spongidae. - Norw. North-Atlantic Exped. 1876-78. Christiania. 25 pp.
- Koltun, V.M., 1958: Cornacuspongida from the Southern Kuriles and Southern Sakhalin. - Issled. dolnevost. Mor. SSSR. 5: 42-77 (In Russian).
- 1959: Cornacuspongida of the Northern and Far Eastern Seas of the USSR. - Akademia NAUK, 67: 1-227 (In Russian; translation 1971).

Untersuchungen zur Bodennepheloidschicht am westlichen Barents See Kontinentalhang



Dissertation
zur Erlangung des Doktorgrades
der Mathematisch-Naturwissenschaftlichen Fakultät
der Christian-Albrechts-Universität
zu Kiel

vorgelegt von
Laurenz Thomsen

Kiel 1992

Dissertation, Juni 1992

Untersuchungen zur Bodennepheloidschicht am westlichen
Barents See Kontinentalhang

Laurenz Thomsen

Zusammenfassung

In der vorliegenden Arbeit wurde die Bodennepheloidschicht am westlichen Barents See Kontinentalhang mit einem für den Einsatz in der Tiefsee neu konstruierten Bodenwasserschöpfer in 10, 15, 25 und 40 cm Höhe sowie mit einem Kranzwasserschöpfer in 500 cm Höhe über Grund beprobt.

Die Untersuchungen fanden während dreier Ausfahrten in das Seegebiet im Sommer 1990 (Meteor 13), Winter 1991 (Poseidon 181) und Sommer 1991 (Meteor 17) statt.

Die Probennahmen während der Meteor 13 Expedition erfolgten vom Barents See Kontinental-schelf in 370 m Tiefe, etwa entlang 75° N bis zum 170 km entfernten Kontinentalsockel in 2500 m Tiefe. Im Zentrum des Untersuchungsgebietes auf 75° N 14° E befand sich ein Hochakkumulationsgebiet mit einer Ausdehnung von ~500 km². Im Bodenwasser der Stationen konnten deutliche Partikel-Konzentrationsgradienten nachgewiesen werden. Von den 14 untersuchten Parametern wurden auf den Stationen der Meteor 13 Expeditionen Sauerstoff, Seston, Chlorophylläquivalente, POC und das Größenspektrum der Bakterien genauer betrachtet.

- Die Sauerstoff-Konzentrationen im Bodenwasser umfaßten während des Untersuchungszeit-raumes einen Bereich von 266 - 376 $\mu\text{mol l}^{-1}$.
- Seston lag im Konzentrationsbereich 1,2 - 11,3 mg l⁻¹ [Median Wert 8 mg l⁻¹].
- Es wurde kein Zusammenhang zwischen den Sauerstoffkonzentrationen im Bodenwasser und der Entfernung zum Meeresboden sowie den Sestonkonzentrationen und der Entfernung zum Meeresboden festgestellt.
- Die Chlorophylläquivalent-Konzentrationen umfaßten einen Bereich von 0,0 bis 0,13 $\mu\text{g l}^{-1}$ [Median Wert 0,05 $\mu\text{g l}^{-1}$] und nahmen in die Wassersäule hinein ab [$P \leq 0,01$].
- Die POC-Konzentrationen schwankten zwischen 16 - 107 $\mu\text{g l}^{-1}$ [Median Wert 52 $\mu\text{g l}^{-1}$] und nahmen bis in 40 cm Höhe über Grund zu [$P \leq 0,01$].
- Auf den Stationen der Meteor 13 Expedition kam es innerhalb der bodennah beprobten Was-serschichten zu einer Verschiebung des Biomasse-Größenspektrums der Bakterien von 10 bis 40 cm Höhe über Grund zu größeren Bakterien. In diesen Wasserschichten waren 35-65% der Bakterien partikelgebunden, während in 500 cm Höhe mindestens 85% des Bakterioplanktons freilebend war.

Im Sommer 1991 wurde während der Meteor 17 Expedition ein *in situ* Experiment am mittleren Kontinentalhang im Zentralbereich der Hochakkumulation in 1340 m Tiefe durchgeführt. Auf drei jeweils eine Seemeile in Strömungsrichtung voneinander entfernten Stationen mit der am Kontinentalhang dichtesten Besiedlung an Suspensionsfressern wurde der Einfluß der Makro-fauna auf Transportvorgänge innerhalb der Bodennepheloidschicht untersucht.

- Eine Abnahme des Sestongehaltes in Strömungsrichtung um bis 41% , der anorganischen Partikel um 59%, der organischen Partikel um 48% sowie die Reduzierung der Bakteriedichte um 35% spiegelte den deutlichen Einfluß eines filtrierenden Polychaetenrasens auf den bodennahen Wasserkörper in 10 - 25 cm Höhe über Grund wieder.
- Der POC-Gehalt des Bodenwassers wurde in Strömungsrichtung um 23% verringert, der Chlorophyllgehalt hingegen um 85% erhöht. Der Chlorophyllgehalt im Sediment erhöhte sich stromabwärts um 58%. Die Abundanz der suspensionsfiltrierenden Polychaeten verringerte sich stromabwärts um 63%.

Aufgrund dieser Ergebnisse wurden folgende Thesen aufgestellt:

- Innerhalb des bodennahen Wasserkörpers findet eine hydrodynamische Sortierung der organischen Fraktion nach leichten und schweren Partikeln statt.
- Der partikuläre organische Kohlenstoff (POC) nimmt mit Abstand zum Meeresboden zu. Partikel dieser Fraktion mit geringer Dichte und Sinkgeschwindigkeit folgen der Strömung und bleiben länger in Suspension. Dadurch gewinnt das Strömungsregime innerhalb der Bodennepheloidschicht eine hohe Bedeutung für die Verbreitung von POC.
- Die in Bodennähe zunehmenden Chlorophyllkonzentrationen im Barents See Untersuchungsgebiet zeigen die Zugehörigkeit des Phythodetritus zur "schweren" organischen Fraktion. Diese organischen Partikel mit hoher Sinkgeschwindigkeit haben nur geringe Aufenthaltszeiten in der bodennahen Wasserschicht, das Strömungsregime wirkt sich nur geringfügig auf ihre Verteilung aus
- Der Eintrag frischen Materials aus der euphotischen Zone erfolgt pulsartig, wobei der Phytodetritus durch Biodeposition und Bioturbation aufgrund seiner geringen Aufenthaltszeiten in den bodennahen Wasserschichten schnell in das Sediment eingetragen wird.
- Feines organisches, refraktäres Material im fortgeschrittenen Abbauzustand oder Partikel lithogenen Ursprungs werden in der Bodenströmung angereichert und überregional verteilt. Die Verbreitung dieses Materials in die Bodennepheloidschicht erfolgt langfristig. Es wird vermutet, daß es in Bodennähe zu anorganischer Partikelflocculation, physikochemischer und mikrobiell-induzierter Aggregatbildung sowie Pelletbildung durch Organismen innerhalb der "leichten" organischen Fraktion (POC) kommt. Auf Aggregate spezialisierte Suspensionsfresser sorgen für die Deposition dieses Materials, welches durch die Besiedlung mit Bakterien eine zusätzliche Nahrungsquelle für Benthosorganismen darstellt.
- Die Ausbildung einer vom Benthos beeinflussten "Internen Boundary Layer" konnte bis in 25 cm Höhe über Grund nachgewiesen werden.

Die Untersuchung zur großräumigen Verteilung partikulärer Substanzen in einer Höhe von 500 cm ü. Gr. mit einer CTD mit Transmissiometer und Wasserschöpfern während der Winterexpedition im Februar-März 1991 ergab folgendes Bild:

- Maximale Attenuationswerte von 23 und 24% wurden um das Kerngebietes des Hochakkumulationsgebietes sowie nordwestlich davon ermittelt.
- Maximale Sestonkonzentrationen von 4 bis 7 mg l⁻¹ wurden mit einer Ausdehnung von ~ 400 km² etwa 10 sm südöstlich des Hochakkumulationsgebietes über der 1500 m Tiefenlinie gemessen.
- Über dem Hochakkumulationsgebiet wurde der nördliche Bereich einer von Süd nach Nord verlaufenden 240 km² großen POC-Wolke mit Werten $\geq 24 \mu\text{g l}^{-1}$ festgestellt, dessen Lage mit dem nördlichen Attenuationspeak übereinstimmte.
- Ein Bereich mit $\geq 3 \times 10^7$ Bakterien l⁻¹ erstreckte sich sichelförmig über das Hochakkumulationsgebiet.

Aufgrund dieser und der oben genannten Ergebnisse wurden folgende Thesen aufgestellt:

- Eine länger anhaltende Versorgung mit frischem Material in das Hochakkumulationsgebiet ist bei einer mittleren, an Kontinentalhängen vorkommenden Strömungsgeschwindigkeit von 10 cm s^{-1} nicht möglich, da die Kohlenstoffquelle "Schelf" schnell erschöpft sein muß.
- Geschätzte Partikelflüsse im bodennahen Bereich des Hochakkumulationsgebietes lassen sich lediglich über die massive horizontale Versorgung von den produktiven Schelfgebieten, durch wirbelartige Strömungen, die über dem Gebiet eine Resuspensionswolke erzeugen und über Kontourströme herantransportierte Partikelwolken bilanzieren. Die möglichen Einzugsgebiete müssen auch bei geringen Strömungen um ein Vielfaches größer als die Depositionsgebiete sein.

Vertical and areal distribution of foraminiferal abundance and biomass in microhabitats around inhabited tubes of marine echiurids

Laurenz Thomsen and Alexander V. Altenbach

SFB 313, Heinrich-Hecht Platz 10, 2300 Kiel 1, Germany

(Received March 14, 1992; revision accepted September 1, 1992)

ABSTRACT

Thomsen, L. and Altenbach, A.V., 1993. Vertical and areal distribution of foraminiferal abundance and biomass in microhabitats around inhabited tubes of marine echiurids. In: M.R. Langer (Editor), *Foraminiferal Microhabitats*. *Mar. Micropaleontol.*, 20: 303–309.

Three examples of microhabitats of foraminifera around inhabited macrofaunal tubes (*Echiurus echiurus*) from the German Bight are given. Compared to ambient sediments, abundances and biomass of foraminifera were up to 3 times higher within the tube. Bacterial abundances were about 2 times higher and bacterial biomass was up to 5 times higher within the tube. Data suggest that tubes and burrows provide microhabitats with increased food concentrations and foraminiferal abundances.

An in situ experiment to investigate the depletion of seston above a suspension feeder field on the continental slope of the western Barents Sea.

Thomsen (1), Graf (2), Juterzenka (3), Witte (4)

ABSTRACT

During "METEOR" Cruise 17 in July 1991 bottom water and sediment samples were taken from 3 stations on a 2 nm long transect on the continental slope of the western Barents Sea (Fig. 1) at 74° 59' N, 14° 40' E. Field profiles of oxygen, total particulate matter, chlorophyll equivalents, calcium carbonate, particulate organic carbon and bacterial abundance in the benthic boundary layer (10 - 40 cm height above sea floor) were taken on the stations upstream across a suspension feeder field at 1370 m water depth. Over a distance of 2 nm between the upstream and downstream stations total particulate matter, particulate organic carbon and bacterial abundance were reduced by 41%, 23% and 35% respectively between 10 - 25 cm height above bed. Chlorophyll equivalents in the bottom water increased by 85%, in the sediments by 58%. Abundance of macrofauna showed no significant correlation to bottom water and sediment data. Compared to sediment trap particle fluxes, real particle sedimentation had to be corrected by a lateral advection factor of 0.7 to 1.7.

1. GEOMAR, Wischhofstr. 1-3, 2300 Kiel 14, F.R.G
2. GEOMAR, Wischhofstr. 1-3, 2300 Kiel 14, F.R.G
3. Inst. f. Polarökologie, Wischhofstr. 1-3, 2300 Kiel 1, F.R.G
4. SFB 313, Heinrich Hecht Platz 10, 2300 Kiel 1, F.R.G

Benthic boundary layer characteristics of the continental margin of the western Barents Sea

Laurenz Thomsen ⁽¹⁾ and Gerhard Graf ⁽²⁾

ABSTRACT

Benthic boundary layer characteristics of the continental margin of the western Barents Sea were studied during three cruises in July 1990, Winter and Summer 1991 by collecting water samples 10, 15, 25, 40 and 500 cm above the sea-floor. On all stations gradients of oxygen and particulate matter within the benthic boundary layer could be determined. Oxygen varied between 266 and 376 $\mu\text{mol l}^{-1}$ and did not correlate with height above the sea-floor. Total particulate matter concentrations ranged from 0.75 to 11.3 mg l^{-1} . Particulate organic carbon concentrations ranged from 16 to 107 $\mu\text{g l}^{-1}$ and Chlorophyll equivalent concentrations ranged from 0.0 to 0.18 $\mu\text{g l}^{-1}$. Bacterial biomass measured on 5 stations varied between 0.05 and 2.07 $\mu\text{g bacterial organic carbon l}^{-1}$ with highest values at 25 and 40 cm height above sea-floor. From 10 to 40 cm above the sea-floor the distribution of individual bacterial volume shift to higher size classes. 10 to 40 cm above the bed 35 to 65 % of the bacteria were particle-associated, while more than 85% of the bacteria were free-living 500 cm above the sea-floor.

Data from the Barents Sea site indicate that, within the suspended matter in the near-bottom water layers particle stratification due to hydrodynamic sorting occurred. Generally particulate organic carbon increased from the seabed into the watercolumn with decreasing values between 40 and 500 cm above the sea-floor. Chlorophyll equivalents decrease above the seabed into the watercolumn. The chlorophyll equivalent / particulate organic carbon ratio in the near-bottom water did not exceed 0.5 %. Data from the Barents Sea site suggest that different processes acting at different time scales control the carbon input to the benthos: Pulse like vertical fluxes of aggregated fresh phyto -and zoodetritrus from the euphotic zone at distinct times of the year, with high settling velocities and low residence times within the benthic boundary layer. Long time horizontal fluxes of organic debris of low nutritional value attached with a bacterial epiflora, with low settling velocities and high residence times within the benthic boundary layer. Carbon input of this material to the benthos could occur via aggregate -and fecal pellet formation.

1,2. GEOMAR, Wischhofstr. 1-3, 2300 Kiel 14, F.R.G

AN INSTRUMENT FOR SAMPLING WATER FROM THE BENTHIC BOUNDARY LAYER

Laurenz Thomsen, Gerhard Graf, Volker Martens and Eric Steen

ABSTRACT

Abstract: The BIOPROBE system, an instrumented tripod is described. It collects water samples and time-series data on physical and geological parameters within the benthic boundary layer in the deep sea at a maximum depth of 4000 m. For biogeochemical studies, four water samples of 15 l each can be collected between 5 and 60 cm above the sea-floor. BIOPROBE contains three thermistor flow meters, three temperature sensors, a transmissometer, a compass with current direction indicator and a bottom camera system. During "METEOR" Cruise 17 in July 1991 BIOPROBE was successfully used on the continental slope of the western Barents Sea at a depth of 1370 m. Analyses of dissolved and particulate matter in layers of 10, 15, 25 and 40 cm above the sea-floor showed strong vertical gradients.

1. SFB 313, Heinrich Hecht Platz 10, 2300 Kiel 1, F.R.G
2. GEOMAR, Wischhofstr. 1-3, 2300 Kiel 14, F.R.G
3. Institut für Meereskunde, Düsternbrooker-Weg 4, 2300 Kiel 1, F.R.G
4. SFB 313, Heinrich Hecht Platz 10, 2300 Kiel 1, F.R.G

BERICHTE

aus dem

SONDERFORSCHUNGSBEREICH 313

VERÄNDERUNGEN DER UMWELT - DER NÖRDLICHE NORDATLANTIK



Nr. 37

Experimente im Strömungskanal zum Einfluß der Makrofauna auf den bodennahen Partikeltransport

WIEBKE ZIEBIS

Zusammenfassung

Der in dieser Arbeit vorgestellte Strömungskanal eignet sich für die Simulation von Feldbedingungen.

Die Messung der Strömungsgeschwindigkeit mit der Thermistorsonde lieferte vertikale Strömungsprofile mit einem charakteristischen Kurvenverlauf, der für die Ausbildung einer bodennahen Grenzschicht kennzeichnend ist.

Erwartungsgemäß nimmt bei zunehmender Strömungsgeschwindigkeit die Dicke der Bodengrenzschicht ab und die Schubspannungsgeschwindigkeit zu.

Die hohe Meßempfindlichkeit und sehr gute räumliche Auflösung der Sonde ermöglichte außerdem die Feststellung einer viskosen Unterschicht, bei einer Strömungsgeschwindigkeit von $1,5 \text{ cm s}^{-1}$ mit einer Schichtdicke von 5 mm.

In einem Resuspensionsversuch wurde die Auswirkung der Erhöhung der Strömungsgeschwindigkeit von $1,5 \text{ cm s}^{-1}$ auf $5,5 \text{ cm s}^{-1}$ und damit einer Erhöhung der Schubspannungsgeschwindigkeit von $0,28 \text{ cm s}^{-1}$ auf $0,88 \text{ cm s}^{-1}$ auf die Partikelresuspension untersucht. Mittels isokinetischer Probennahme wurde der Sestongehalt innerhalb der Bodengrenzschicht ermittelt und ergab eine Konzentrationerhöhung um 58 %, von $8,2 \text{ mg l}^{-1}$ auf $12,6 \text{ mg l}^{-1}$. Das bedeutet eine Partikelresuspension (Efflux) aus dem Sediment in die Wassersäule von $1,5 \text{ g m}^{-2}$.

Aus der Partikelkonzentration und der Strömungsgeschwindigkeit in der entsprechenden Höhe über dem Sediment konnte der Partikelfluß errechnet werden. In einer Höhe von 8 und 15 mm über der Sedimentoberfläche stieg er bei diesem Experiment um 800 %.

Es wurde eine Methode entwickelt, um Mikrosphären (fluoreszierende Latexpartikel) vom Sediment zu trennen. Die hohe Wiederfundrate von 45 % ermöglichte die Verfolgung des Partikeltransportes von der Wassersäule ins Sediment, und damit eine Abschätzung der Depositionsraten.

Die Möglichkeit, einen intakten Sedimentkern mit natürlicher Besiedlung in die Anlage so einzufügen, daß er mit der Kanalbodenfläche, die mit gesiebten Sediment der selben Station bedeckt ist, eine ebene Fläche bildet, ermöglicht den Vergleich zwischen Biodeposition und gravitativer Deposition.

Es konnte gezeigt werden, daß Makrofaunaorganismen wesentlich zur Deposition partikulären Materials beitragen. Die Biodeposition war auf der Sedimentkernfläche um den Faktor 3,5 gegenüber der Vergleichsfläche erhöht.

Die Mikrosphären können als interner Standard genutzt werden, um die Gesamtdeposition abzuschätzen. Der Eintrag partikulären Materials aus der Wassersäule ins Sediment betrug demnach auf der Kernoberfläche $232 \text{ mg m}^{-2} \text{ d}^{-1}$ im Vergleich zu $66 \text{ mg m}^{-2} \text{ d}^{-1}$ auf der unbesiedelten Fläche.

Es konnte gezeigt werden, dass besonders die Deposition feinen Materials, das sonst nicht absinken würde, durch den Einfluß der Makrofaunaorganismen um ein Vielfaches gesteigert wurde, die Anzahl kleiner Partikel ($1 \text{ }\mu\text{m}$, $2 \text{ }\mu\text{m}$, $3 \text{ }\mu\text{m}$ und $6 \text{ }\mu\text{m}$) erhöhte sich um das 6 -10 fache.

Die Betrachtung eines 'Mikrokosmos' ermöglichte die genaue Untersuchung der Interaktionen der Makrofauna mit dem horizontalen Partikelfluß und ihrer Bedeutung für die Biodeposition. Allein durch die Veränderung der Oberfläche (Mikrotopographie) und damit des kleinskaligen Strömungsregimes über der Sedimentoberfläche tragen die Organismen indirekt zu einer erhöhten Deposition bei. (Faktor 1,7).

Die untersuchte Tiergemeinschaft bestehend aus *Macoma baltica* und *Pectinaria koreni* kann mit einem Suspensionsfresser- Depositionsfresser Modell dargestellt werden, das einen interspezifischen Nahrungstransfer beschreibt und auf die Bedeutung von Biodepositen als Nahrungszufuhr für Depositionsfresser hinweist. Unter dem Einfluß einer Bodenströmung leistet *M. baltica* als Suspensionsfresser mit 38 bis 56 % den größten Beitrag zur Biodeposition. Das unter der Sedimentfläche in Form von Pellets deponierte Material steht hier dem Depositionsfresser *P.koreni* zur Verfügung.

Teilprojekt A4:

Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian-Greenland Sea

STOFFUMSATZ IM BENTHAL

R. Botz^a, H. Erlenbeuser^a, J. Koch^a and H. Wehner^a

^aGeologisch-Paläontologisches Institut, Universität Kiel, Olshausenstrasse 46-50, 2300 Kiel, Germany

^bInstitut für Kernphysik, G14-Lab, Universität Bonn, Sigmund-Freud-Strasse 40-49, 5300 Bonn, Germany

^cBundesanstalt für Geowissenschaften und Rohstoffe, 3000 Hannover 52, Germany

(Received July 3, 1990; revision accepted October 30, 1990)

Kurzfassungen

ABSTRACT

Botz, R., Erlenbeuser, H., Koch, J. and Wehner, H., 1991. Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian-Greenland Sea. *Mar. Geol.* 95: 113-119.

Organic geochemical investigations of Norwegian Sea sediments deposited during oxygen isotope stages 6 and 5 show significant changes in the relative amount of "reactive" (bitumens and opaloids) and "inert" (keratins and graphite) particles. The $\delta^{13}\text{C}$ values of the total organic fractions possibly reflect the variable content of reactives, i.e. the isotopic composition is more negative (to -23.5%) when the reactive components increase. The n-alkane distribution shows that the sediments deposited during late stage 6 and 5a contain relatively low odd-odd carbon number indices (C₂₇) associated with shorter chain lengths. This indicates a relatively higher marine algal contribution during stage 6 and 5a compared with stage 5b to 5c.

Introduction

Sediments from the Norwegian Sea area show various lithofacies types ranging from brownish foraminiferal ooze to very dark grey mud relatively rich in organic matter (Eideholm et al., 1987; Henrich et al., 1988). These various sediment types are thought to be related to the paleoceanographic conditions in the Norwegian Sea (Henrich et al., 1989). The comparatively organic-rich sediments occur in all sediment cores investigated from the Norwegian Sea. However, the distinct organic-rich layers may be the result of one or diverse sedimentation processes. The presence of high amounts of algal-derived organic matter in the sediments is either related to bioproductivity maxima (or very low sedimentation rate of inorganic material) or it could also reflect a low decomposition rate within the water column or sediment. On the other hand, based on earlier investigations, organic matter of terrestrial origin was found to signifi-

cantly contribute to the organic content of the sediments too (Debyser et al., 1977). Thus, paleoceanographic conclusions if based on the variable amounts of organic matter (OM) in sediments alone are possibly misleading. Instead, the type and composition of the organic matter may be more help in distinguishing whether its character is autochthonous or allochthonous, and, thus, should allow speculation about the paleoceanographic conditions prevailing during sedimentation.

Materials and methods

This study concentrated on sediment cores 13639-3 from the Norwegian-Greenland Sea (Fig. 1). The core was retrieved from a water depth of 2253 m and it is 615 cm long. The lithofacies and sediment stratigraphy have been described in detail by Henrich et al. (1989). The samples taken for the present study were from a core depth of 150-250 cm

Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian–Greenland Sea

R. Botz^a, H. Erlenkeuser^b, J. Koch^c and H. Wehner^c

^a*Geologisch–Paläontologisches Institut, Universität Kiel, Olshausenstrasse 40–60, 2300 Kiel, Germany*

^b*Institut für Kernphysik, C14-Lab, Universität Kiel, Olshausenstrasse 40–60, 2300 Kiel, Germany*

^c*Bundesanstalt für Geowissenschaften und Rohstoffe, 3000 Hannover 51, Germany*

(Received July 3, 1990; revision accepted October 30, 1990)

ABSTRACT

Botz, R., Erlenkeuser, H., Koch, J. and Wehner, H., 1991. Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian–Greenland Sea. *Mar. Geol.*, 98: 113–119.

Organic petrographical investigations of Norwegian Sea sediments deposited during oxygen isotope stages 6 and 5 show significant changes in the relative amounts of "reactive" (vitrinite and liptinite) and "inert" (inertinite and graphite) particles. The $\delta^{13}\text{C}$ values of the total organic fraction possibly reflect the variable content of reactives, i.e. the isotopic composition is more negative (to -23.9%) when the reactive components increase. The *n*-alkane distribution shows that the soluble organic matter deposited during late stage 6 and 5e reveals relatively low odd–even-predominance indices (OEP) associated with shorter chain lengths. This indicates a relatively higher marine algal contribution during stage 6 and 5e compared with stage 5d to 5a.

Introduction

Sediments from the Norwegian Sea area show various lithofacies types ranging from brownish foraminiferal ooze to very dark grey mud relatively rich in organic matter (Eldholm et al., 1987; Henrich et al., 1989). These various sediment types are thought to be related to the paleoceanographic conditions in the Norwegian Sea (Henrich et al., 1989). The comparatively organic-rich sediments occur in all sediment cores investigated from the Norwegian Sea. However, the distinct organic-rich layers may be the result of one or diverse sedimentation processes. The presence of high amounts of algal-derived organic matter in the sediments is either related to bioproductivity maxima (or very low sedimentation rate of inorganic material) or it could also reflect a low decomposition rate within the water column or sediment. On the other hand, based on *n*-alkane investigations, organic matter of terrestrial origin was found to signifi-

cantly contribute to the organic content of the sediments too (Debyser et al., 1977). Thus, paleoceanographic conclusions if based on the variable amounts of organic matter (OM) in sediments alone are possibly misleading. Instead, the type and composition of the organic matter may be more help in distinguishing whether its character is autochthonous or allochthonous, and, thus, should allow speculation about the paleoceanographic conditions prevailing during sedimentation.

Materials and methods

This study concentrated on sediment core 23059-3 from the Norwegian–Greenland Sea (Fig. 1). The core was retrieved from a water depth of 2258 m and it is 615 cm long. The lithofacies and sediment stratigraphy have been discussed in detail by Henrich et al. (1989). The samples taken for the present study were from a core depth of 150–258 cm.

Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian-Greenland Sea

R. Bock, H. Erlenkeuser, J. Koch, and H. Wobner

Nr. 35

Mikrobieller Abbau von organischem Material an Grenzزونen

- erläutert an Beispielen von Sedimenten der Nordsee und des Europäischen Nordmeeres

Marion Köster

Zusammenfassung

Diese Arbeit beschäftigt sich mit dem mikrobiellen Abbau und der Ablagerung von organischem Material in Sedimenten der Nordsee und des Europäischen Nordmeeres. Geschwindigkeitsbegrenzender Schritt bei der mikrobiellen Oxidation von organischem Kohlenstoff ist die enzymatische Hydrolyse von höhermolekularem organischen Material. Die aus der Hydrolyse resultierenden niedermolekularen Spaltprodukte können von den Mikroorganismen aufgenommen werden und dienen teils der Respiration und teils der Biomasseproduktion. Die Abbauprozesse von organischem Material wurden insbesondere an Grenzzonen, wie Sedimentoberfläche, Redoxsprungschicht und biogenen Strukturen der Epi- und Infauna, untersucht. Generell waren diese Grenzzonen durch ausgeprägte Gradienten chemischer und physikochemischer Parameter sowie durch erhöhte mikrobielle Aktivitäten gekennzeichnet.

In Sedimenten der Nordsee steuerten saisonal und lokal variierende Umgebungsfaktoren den enzymatischen Abbau von organischem Material. Neben Temperatur und Nährstoffversorgung beeinflusste die Bioturbation der Makrofaunaorganismen wesentlich die Konzentration, den Abbau und die Ablagerung von organischem Material. In bioturbaten Sedimenten wurde eingetragenes organisches Material schnell in das Sediment eingearbeitet und überwiegend in intermediären Sedimenthorizonten modifiziert und abgebaut. Die Aktivitäten der Makrofaunaorganismen führten zu relativ homogenen Profilen von mikrobiellen Besiedlungsmustern und Abbauprodukten. Weitgehend unbesiedelte Sedimente wiesen hingegen stark ausgeprägte Gradienten chemischer, physikochemischer und mikrobieller Parameter auf. In diesen Sedimenten wurden insbesondere an der Redoxsprungschicht erhöhte mikrobielle Aktivitäten festgestellt.

In pelagischen Sedimenten des Europäischen Nordmeeres konnte experimentell durch einen Eintrag von organischem Material in das Sediment nachgewiesen werden, daß die Verfügbarkeit von Nährstoffen der wichtigste Steuerungsfaktor für mikrobielle Substratsätze war. Natürlicher Detritus wurde schnell in das Sediment

eingearbeitet und induzierte mikrobielle enzymatische Abbauaktivitäten. In pelagischen Sedimenten wirkte sich der Druck nicht stimulierend auf die enzymatischen Abbauaktivitäten aus. Der Pool hydrolytischer Enzyme zeigte weder barophilen noch psychophilen Charakter.

Abbau- und Ablagerungsmuster von organischem Material wurden zudem wesentlich durch unterschiedliche benthische Besiedlungsstrukturen geprägt. Stark ausgeprägte Gradienten mikrobieller Abbauaktivitäten in Oberflächensedimenten der Jan Mayen Bruchzone waren mit dem Vorkommen von epibenthischen Foraminiferen assoziiert. In bioturbaten Sedimenten des Vøring-Plateaus konzentrierten sich mikrobielle Abbauaktivitäten vornehmlich an Infaunastrukturen. In Sedimenten am Kontinentalhang der westlichen Barentssee wurden verschiedene Abbau- und Ablagerungsmuster von organischem Material in Abhängigkeit von der Nährstoffversorgung und benthischen Besiedlung beobachtet. In Sedimenten auf dem Schelf mit einer hohen Nährstoffzufuhr kam es im Zuge der suboxischen Diagenese mit zunehmender Sedimenttiefe zu einer bevorzugten Mineralisierung von organischem Stickstoff (N-Abreicherung). Demgegenüber begrenzte in Sedimenten am Kontinentalfuß der organische Kohlenstoff die benthischen Abbauaktivitäten. Aus einer bevorzugten Mineralisierung von Kohlenstoff resultierte eine relative Anreicherung von Stickstoff gegenüber Kohlenstoff. Hingegen zeigte sich an Stationen mit hohen Akkumulationsraten am Kontinentalhang generell hinsichtlich der Zusammensetzung an organischem Kohlenstoff und Stickstoff keine Veränderung des organischen Materials in den Sedimentprofilen.

Die in den Untersuchungen aufgezeigten Beziehungen zwischen enzymatischen Abbauaktivitäten, Konzentration an organischem Material, Respiration, Bakterienzahl und Biomasseproduktion verdeutlichen die Schlüsselstellung des enzymatischen Abbaus von organischem Material. Während sich in Sedimenten des Europäischen Nordmeeres direkte Wechselbeziehungen zwischen den genannten Parametern nachweisen ließen, führten in Nordseesedimenten variierende Umgebungsparameter zu saisonal und räumlich stark variierenden Wechselbeziehungsmustern.

3 Mikrobielle Aktivitäten an Grenzflächen

Marion Köster

Zusammenfassung

3.1 Einleitung

3.2 Die Bedeutung enzymatischer Abbauaktivitäten für mikrobielle Substratumsätze

3.3 Mikrobieller Abbau von organischem Material an der Sedi- ment/Bodenwasser-Kontaktzone

3.3.1 Bedeutung der bodennahen Grenzzone ("benthic boundary layer")

3.3.2 Reaktion der Benthosorganismen auf Nährstoffeinträge

3.3.3 Variationen mikrobieller Abbauprozesse in Küstensedimenten

3.3.4 Mikrobielle Populationsstrukturen

3.4 Mikrobielle Aktivitäten an der Redoxsprungschicht

3.4.1 Lokale und saisonale Dynamik der Redoxsprungschicht

3.4.2 Stimulation benthischer Aktivitäten

3.5 Einfluß biogener Strukturen auf den Abbau und die Ablagerung von organischem Material

3.5.1 Einfluß der Epifauna auf Konzentrations- und Abbaumuster von organischem Material

3.5.2 Stimulation mikrobieller Aktivitäten durch Infaunaorganismen

3.5.3 Einfluß benthischer Lebensgemeinschaften auf die Diagenese von organischem Material

Literatur

Zusammenfassung

Die Heterogenität mariner Sedimente wird durch eine Vielzahl komplexer Lebensräume charakterisiert, zu denen insbesondere Grenzflächen bzw. Grenzzonen zählen, denen bei mikrobiellen Substratumsätzen eine besondere Bedeutung zukommt. Zu den wichtigsten Grenzzonen, deren Bedeutung für den mikrobiellen Abbau von organischem Material in diesem Kapitel diskutiert wird, zählen die bodennahe Grenzzone ("benthic boundary layer"), die Sediment/Wasser-Kontaktzone, die Redoxsprungschicht sowie biogene Strukturen der Meio- und Makrofauna.

An Grenzzonen, wo verschiedene Lebensräume miteinander in Wechselbeziehung treten, entstehen ausgeprägte Gradienten biologischer, chemischer und physikochemischer Parameter, die Ausdruck mikrobieller Aktivitäten sind und sich in charakteristischen Besiedlungs- und Aktivitätsmustern widerspiegeln. Da der überwiegende Teil des in das Sediment eingetragenen organischen Materials partikulärer Natur ist, stellt die enzymatische Hydrolyse den einleitenden und geschwindigkeitsbegrenzenden Schritt in der mikrobiellen Oxidation organischen Kohlenstoffs dar. Deshalb kommt der Messung des enzymatischen Abbaus von partikulärem Kohlenstoff in Sedimenten besondere Bedeutung zur Charakterisierung mikrobieller Abbauaktivitäten zu.

Da die Nährstoffversorgung mariner Sedimente generell durch Sedimentation aus der Wassersäule erfolgt, sind wesentliche Abbauprozesse an der Sediment/Bodenwasser-Kontaktzone lokalisiert, an der eine hohe Variabilität in den Konzentrations- und Abbaumustern von organischem Material beobachtet wird. Mikrobielle Populationsstrukturen und Abbauaktivitäten an der Sediment/Bodenwasser-Kontaktzone werden dabei durch die Dynamik der bodennahen Grenzzone ("benthic boundary layer") beeinflusst. Nährstoffeinträge führen zu einer unmittelbaren Stimulation benthischer Aktivitäten. Der überwiegende Teil des in das Sediment eingetragenen organischen Materials wird in oberflächennahen Horizonten modifiziert und abgebaut.

In küstennahen Sedimenten besitzt die Redoxsprungschicht eine besondere Bedeutung für die Diagenese von organischem Material. In dieser Grenzzone, die durch die größte Änderung des Redoxpotentials angezeigt wird, bedingen heterotrophe Abbauprozesse sowie die Oxidation reduzierter Komponenten des anaeroben Stoffwechsels die Koexistenz unterschiedlicher physiologischer Gruppen von Mikroorganismen. Lage und Ausdehnung der Redoxsprungschicht unterliegen einer hohen saisonalen und lokalen Dynamik und werden wesentlich durch die Nährstoffzufuhr und die daraus resultierenden mikrobiellen Aktivitäten bestimmt.

Neben großflächigen Grenzzonen spielen im kleinräumigen Bereich biogene Strukturen eine bedeutende Rolle als Orte intensiver mikrobieller Abbauprozesse. Durch Aktivitäten der Meio- und Makrofauna werden Flüssigkeits- und Partikeltransporte intensiviert. Gangsysteme und fecal pellets benthischer Invertebraten stellen Mikrohabitate für Mikroorganismen dar, die verstärkt besiedelt werden und eine Stimulation mikrobieller Abbauprozesse bedingen. Zudem ist ein wesentlicher Teil des Abbaus von organischem Material in Verdauungssystemen von Benthosorganismen lokalisiert. Am Beispiel von Sedimenten des Europäischen Nordmeeres konnte gezeigt werden, daß der Abbau und die Ablagerung von organischem Material in charakteristischer Weise durch die benthische Besiedlung geprägt werden.

Die Ausführungen unterstreichen die Bedeutung feinskaliger Untersuchungen zur Erfassung mikrobieller Abbauprozesse in Sedimenten. Hierfür sind Methoden erforderlich, die eine räumliche Auflösung im Wirkungsbereich von Mikroorganismen gewährleisten. Messungen mikrobieller Substratumsätze müssen von abiotischen und biotischen Parametern zur Charakterisierung des diagenetischen Milieus begleitet werden.

Availability of nutrients to a deep-sea benthic microbial community: results from a ship-board experiment

M. Köster, O. Charfreitag and L.-A. Meyer-Reil

Institut für Meereskunde an der Universität Kiel
Düsternbrooker Weg 20, D-2300 Kiel, Germany

Abstract

Intact sediment cores from the Vøring-Plateau (Norwegian Sea) were incubated under *in situ* temperature on board ship with and without the addition of natural detritus to follow the reaction of deep-sea benthic microbial communities to nutrient enrichment. Concentration and enzymatic decomposition of organic material, total microbial number, biomass and production were followed in time-course experiments. The addition of decomposable organic material caused an immediate stimulation of microbial metabolic processes: following the induction of enzymatic activity, microbial biomass production increased.

During the initial period of incubation metabolic processes were also stimulated in the untreated "control" sediments. This "incubation effect" competed with the "feeding effect" caused by the enrichment with organic material.

Introduction

Distribution and activity of microbial communities in deep-sea sediments are governed by the supply with organic material (TURLEY and LOCHTE 1989) which only episodically enters the seafloor. As described by several authors (e.g. HELDER 1989, MURRAY and KUIVILA 1990), most of the sedimented organic material is oxidized by oxygen and secondary oxidants at the sediment surface. Very little, however, is known about the degradation of organic material in deep-sea sediments as well as about the organisms involved. Therefore a laboratory experiment was carried out, in which the reaction of deep-sea benthic microbial communities to an input of natural detritus was investigated.

Material and methods

Sampling. Sediment cores from the Norwegian Sea (Vøring-Plateau; water depth 1240 m; 67°44'1"N, 05°55'0"E) were incubated on board ship under *in situ* temperature (- 0.5 °C). After 4 days of "acclimatization", one set of the cores was enriched with detrital material, the remaining untreated cores served as controls. The response of microbial communities to the enrichment was followed by analysing various chemical and microbiological parameters in the sediment profiles. For the analyses, sediments were dissected in 0.5 and 1.0 cm intervals,

19

Hydrolytic Activities of Organisms and Biogenic Structures in Deep-Sea Sediments

Marion Köster, Preben Jensen, and Lutz-Arend Meyer-Reil

19.1 Introduction

Benthic activities such as feeding, burrow construction, and locomotion significantly affect the distribution and rate of organic matter decomposition (Aller, 1982; 1988; Aller and Aller, 1986; Aller and Yingst, 1985; Andersen and Kristensen, 1988; Kristensen, 1988; Kristensen and Blackburn, 1987); for instance, the capture of organic-rich particles by the protoplasmic net of foraminiferans, the transport of freshly sedimented organic particles into deeper sediment layers by bioturbation, and the accumulation of organic matter in the digestive tract of organisms all cause organic matter degradation to be concentrated at special sites in the sediment.

Previous investigations of the impact of biogenic structures on the turnover of organic matter have concentrated on shallow-water coastal sediments. It has been shown that burrows and fecal pellets of macrofaunal organisms offer microenvironments for a broad spectrum of physiological groups of micro- and meiofauna (Meyers et al., 1987; Reichardt, 1988; Reise, 1987). Microbial decomposition rates are usually elevated in these microhabitats (Aller and Aller, 1986; Alongi, 1985; Reichardt, 1986). However, very little is known about the contribution of benthic organisms to organic matter decomposition in deep-sea sediments. Sediments of the Norwegian-Greenland Sea, located in the Jan Mayen Fracture Zone (water depth between 1,200 and 1,800 m) were colonized by mass abundances of epibenthic foraminiferans (belonging to the genera *Hyperammina* and *Reophax*), whereas sediments from the Vøring Plateau (water depth 1,240 m) were characterized by bioturbating macrofauna organisms, such as

enteropneusts, echinurans, anthozoans, and sipunculans (Romero-Wetzel, 1987; 1989). These in- and epifaunal benthic organisms significantly affect organic matter decomposition rates in deep-sea sediments of the Norwegian-Greenland Sea.

The enzymatic hydrolysis of particulate organic matter is the initial and rate-limiting step of the organic carbon oxidation process in sediments. However, at the present time, the direct measurement of organic matter degradation under in situ conditions is limited by a number of methodological problems. Therefore radioactive or dye-labelled artificial substrates represent useful tools in the study of organic matter hydrolysis. Among the dye-labelled substrates, fluorescein diacetate (FDA) has been proved as a suitable model substrate, which is hydrolyzed rather unspecifically by esterases (see Chapter 5).

In this study, sediments from the Norwegian-Greenland Sea were analyzed for hydrolytic activity associated with biogenic structures (meio- and macrofauna organisms as well as their tubes and burrows) using fluorescein diacetate as a model substrate. In comparison with the hydrolytic activity measured in the bulk phase sediment, the importance of biogenic structures for organic matter decomposition in deep-sea sediments becomes obvious.

19.2 Methods

Sediment samples from the Norwegian-Greenland Sea were taken by a large Reineck box corer during two expeditions with R.S. "Meteor" in August/September 1988 (cruise M7/4-5) and in June/July 1989 (cruise M10/3). The positions of the stations are indicated and specified in Figure 19.1. Sediments were screened for dominating meio- and macrofauna organisms. Infaunal organisms were prevailing at the station on the Vøring Plateau (station 533), whereas stations located in the Jan Mayen Fracture Zone (stations 576, 625, 635, and 681) were generally characterized by a rich fauna of epibenthic foraminiferans (*Hyperammina* and *Reophax* spp.). Beside the organisms, sediment was collected from the burrows of the organisms as well as the surrounding sediment. At the time of sampling, the temperature of the sediment surface ranged between -1°C and $+1^{\circ}\text{C}$.

In order to analyze the hydrolytic activity associated with biogenic structures in deep-sea sediments, individuals of enteropneusts (*Stereobalanus canadensis*), echinurans (not identified), and anthozoans (*Cerianthus voglii*) were dissected. In the case of echinurans and anthozoans, only one individual tube dwelling organism was available for enzymatic analyses. All the organisms were homogenized with a teflon pestle and diluted in filter-sterilized bottom water. Organisms, that were too small to be dissected (polychaetes, ophiuroids, sipunculans, and foraminiferans) were treated as a whole. The selected dilution was dependent on the amount of homogenized material. Sediment cores were dissected at 2.5-mm intervals and diluted 1:5.

The enzymatic assay was started by adding fluorescein diacetate (Serva) at

VARIATIONS IN THE DISTRIBUTION OF HYDROCARBONS AT THE WESTERN BARENTS SEA CONTINENTAL SHELF: A COMPARISON OF SEDIMENT TRAP MATERIAL AND SURFACE SEDIMENTS

J. MAABEN, D. SCHULZ-BULL and J.C. DUINKER
SFB 313 University Kiel
Institut of Marine Research, Kiel

Abstract:

Seasonal variations of fluxes of n-alkanes, n-alkenes and isoprenoids were analysed in particulate matter during a sediment trap exposition period from March to July 1991. Therefore three sediment traps with a resolution of 7 days were moored at the edge of the western Barents Sea Continental Shelf. The particulate matter sampled in depths of 610 m, 1800 m and 1900 m was compared with several surface sediments within the sampling area. Gas chromatographic and gas chromatographic-mass spectrometric techniques were used to separate and quantify the hydrocarbons.

The strong input of fresh biogenic material from the euphotic zone during the summer time is shown by an unbranched alkene with 22 carbon atoms and 6 double bonds, n-C_{22:6} with a flux of about 700 ng m⁻²d⁻¹ in the deeper traps. The seasonal variation of the n-alkanes is in good correlation with the POC flux. The Σ n-alk(C₁₄ to C₃₇) increases about ten times up to 700 ng m⁻²d⁻¹ at 610 m during the summer phytoplankton bloom, while deeper traps show maximum fluxes with values of 200-260 ng m⁻²d⁻¹.

The n-alkane distributions in the deeper traps show lateral inputs of organic poor material. This events were found in the early spring, while the productivity in the surface waters was low. Comparison with the surface sediments indicate an input from the Barents Sea Continental Shelf.

to be submitted to *Cont. Shelf Res.* (1993)

5

Ecological Aspects of Enzymatic Activity in Marine Sediments

Lutz-Arend Meyer-Reil

5.1 Introduction

The supply of organic material is a key factor determining the structure and activity of benthic microbial communities. The overwhelming portion of the organic matter entering the sediment via sedimentation is particulate organic carbon, which has to be extracellularly decomposed by enzymes prior to incorporation into microbial cells. The enzymatic hydrolysis of higher-molecular-weight material is considered to be the rate-limiting step in the process of organic matter oxidation in sediments (Billen, 1982; Meyer-Reil, 1987b). The decomposition processes are controlled by microbial (exclusively bacterial?) enzymes which degrade polymeric compounds extracellularly, and their oligomeric products become available substrates for uptake by microbial cells. If the hydrolysis products are not taken up directly, they are fed into the pool of dissolved substrates in sediments. Through microbial attack on particles, refractory organic carbon becomes more easily assimilable for higher trophic levels (Meyer-Reil, 1983).

The direct measurement of enzymatic activity by chemical analysis of the degradation products in natural ecosystems is usually limited by a number of methodological problems (e.g., unknown spectrum and composition of natural substrates and decomposition products, incorporation of products of enzymatic catalysis into microbial biomass). Therefore, radioactive or dye-labelled model substrates represent useful tools in the study of enzymatic activity in sediments. In this chapter, only dye-labelled substrates will be considered.

Extracellular enzymes, as opposed to intracellular enzymes, are defined as those acting outside the cell, however, they may be localized on the outer cell membrane. The term *exoenzyme*, as opposed to *endoenzyme*, is used to characterize the location of enzymatic hydrolysis. Exoenzymes attack polymers at

terminal locations, liberating oligomeric or monomeric substrate subunits. Endoenzymes cleave the central structure of polymers, liberating relatively large units. According to the definitions given above, an enzyme that is bound to the outer cell membrane and releases small subunits from biopolymers has to be characterized as an extracellular exoenzyme in the strict sense. However, as will become evident from the discussion below, our limited knowledge of enzymes acting in natural sediments does not allow their unequivocal characterization according to their localization and mode of attack.

This article summarizes the ecological aspects of enzymatic activity in marine sediments. Beside the methodological approach, observations on the localization of enzymes, their spatial distribution, and the regulation of activity will be discussed. From these presentations it will become obvious that our present knowledge of the functioning of enzymes in natural sediments comprises a narrow range of casual observations and measurements which are far away from a detailed understanding of the enzymatic processes controlling organic matter degradation.

5.2 Methodological Approach

Although dye-labelled particulate enzyme substrates have been available for some time, they have not been extensively used in ecological studies (e.g., Kim and ZoBell, 1974; Little et al., 1979; Meyer-Reil, 1981; 1983). Recently, the dye-labelling of structural biopolymers with "reactive" covalent-bound dyes has been proposed by Reichardt (1986; 1988) as a simple method to label natural substrates for measuring their enzymatic solubilization. The decomposition processes can be easily followed as an increase of absorbance resulting from the release of soluble, dye-containing, hydrolytic products. The advantage of this method is that a broad spectrum of both chemically-defined and complex natural substrates can be labeled with reactive dyes. However, the assays have to be carefully standardized with regard to concentration and particle size of the substrate, extraction of enzymes from the sediment, and adsorption of dissolved reaction products to sediment particles (Reichardt, 1988). My own investigations using commercially available particulate dye-labelled substrates (Amylopectin Azure, Hide Powder Azure) have shown that microbial colonization was necessary for hydrolytic attack in natural sediments. This observation provides a possible explanation for the dependence of the hydrolysis rates on substrate-particle size reported by Reichardt (1988).

Beside the above mentioned dye-labelled insoluble particulate substrates, soluble fluorogenic analogs of organic substrates have been applied to natural sediment samples (King, 1986; Meyer-Reil, 1986; 1987a). Among these substrates, fluorescein diacetate (FDA) and methylumbelliferyl (MUF) derivatives of various organic compounds are probably most commonly used. Whereas the dye derivative is relatively nonfluorescent, the hydrolytic degradation product is highly fluorescent, thus facilitating the sensitive determination of enzymatic hydrolysis rates after relatively short incubation times.

In: CHROST, R.J.: Microbial Enzymes in Aquatic Environments (1991). Springer-Verlag, New York: 84-95

2 Mikrobielle Besiedlung und Produktion

Lutz-Arend Meyer-Reil

Zusammenfassung

2.1 Einleitung

2.2 Bestimmungen mikrobieller Zellzahl und Biomasse

- 2.2.1 Probenentnahme
- 2.2.2 Biochemische Indikatoren
- 2.2.3 Kulturverfahren
- 2.2.4 Mikroskopische Analysen

2.3 Mikrobielle Besiedlung von Partikeln

2.4 Räumliche Verteilung von Zellzahl und Biomasse

- 2.4.1 Lokale Variationen
- 2.4.2 Tiefenabhängige Variationen

2.5 Struktur mikrobieller Biomasse

2.6 Zellzahl und Biomasse in Beziehung zu Sedimentparametern

- 2.6.1 Zellzahl und Korngröße
- 2.6.2 Biomasse und organischer Gehalt

2.7 Zeitliche Entwicklung von Zellzahl und Biomasse

- 2.7.1 Tagesrhythmische Fluktuationen
- 2.7.2 Jahreszeitliche Schwankungen

2.8 Mikrobielle Produktion

- 2.8.1 Abbau von organischem Material
- 2.8.2 Bestimmung der mikrobiellen Produktion
- 2.8.3 Effektivität des Abbaus von organischem Material

2.9 Schlußfolgerungen

Literatur

Zusammenfassung

Ein Charakteristikum mikrobiellen Lebens in Sedimenten ist die Besiedlung von Partikeln. Moderne mikroskopische Techniken stellen den einzigen direkten Weg dar, um die Besiedlung sowie die Gesamtzahl und Biomasse von Mikroorganismen (Bakterien) in Sedimenten zu erfassen. Auch wenn die epifluoreszenzmikroskopische Analyse von Bakterienpopulationen heute als Routinemethode angesehen wird, so muß berücksichtigt werden, daß die Methode insbesondere in Sedimenten mit einem erheblichen subjektiven "Fehler" belastet sein kann, der sich durch die Umrechnungsmultiplikatoren schnell fortpflanzt. Hier sind dringend Methoden erforderlich, die die eindeutige Identifizierung von Bakterien erlauben. Die Extrapolation mikrobieller Biomasse auf Kohlenstoff unterliegt in Abhängigkeit von den verwendeten Umrechnungsfaktoren einer beträchtlichen Variationsbreite. Die Verwendung chemischer Zellkomponenten als Indikatoren für mikrobielle Biomasse ist problematisch. Die Komponenten sind entweder universell bei Pro- und Eukaryonten verbreitet (z.B. Phospholipide), sie sind spezifisch für einzelne physiologische Gruppen von Bakterien (z.B. Lipopolysaccharide) oder sie liegen in unterschiedlichen Konzentrationen in verschiedenen physiologischen Gruppen vor (z.B. Muraminsäure). Hinzu kommt das Problem der Umrechnung auf Biomasse (Kohlenstoff).

Die Mikroorganismen auf den Partikeloberflächen sind eingebettet in eine organische Matrix aus extrazellulären polymeren Substanzen, die die Zellen vor plötzlichen Veränderungen ihrer Umgebungsparameter schützen und ein interzelluläres Kommunikationsmedium darstellen. Über die Dynamik der mikrobiellen Besied-

lung von Partikeloberflächen sowie über die Struktur und Funktion mikrobieller Biofilme in natürlichen Sedimenten ist bislang wenig bekannt. Mikrobielle Zellzahlen und Biomasse unterliegen ausgeprägten standortbedingten und tiefenabhängigen Variationen. Die Zahlen variieren zwischen 10^8 und 10^{10} Zellen g^{-1} Sediment, die Biomasse zwischen 1 und 1 000 μg Kohlenstoff g^{-1} . Generell bilden die kleinsten Größenklassen die größte mikrobielle Biomasse. Im Vergleich zu sandigen Sedimenten beherbergen schlickige Sedimente höhere Zellzahlen und Biomasse. Mikrobieller Kohlenstoff bildet nur einen relativ geringen Anteil am organischen Kohlenstoff der Sedimente (0,6 - 8,5%).

Die mikrobiellen Populationen unterliegen ausgeprägten jahreszeitlichen Variationen, die neben der Temperatur entscheidend durch den Eintrag von Nährstoffen in das Sediment gesteuert werden. Mikroorganismen reagieren unmittelbar auf die Verfügbarkeit von Nährstoffen mit einer kräftigen Biomasseproduktion, wobei drastische Verschiebungen im Größenspektrum der mikrobiellen Biomasse beobachtet werden. Erst nachfolgend wird die Teilungsaktivität stimuliert. In Flachwassersedimenten zeigen mikrobielle Aktivitäten tagesrhythmische Fluktuationen in enger Abhängigkeit von der Primärproduktion. Methoden zur Bestimmung der bakteriellen Produktion, insbesondere die Inkorporation von Vorläufern der Nukleinsäuresynthese in Makromoleküle, werden in der Literatur diskutiert. Die bislang vorliegenden Daten zeigen, daß zwischen $0,1$ und $10 g C m^{-2} d^{-1}$ durch bakterielle Sekundärproduktion gebildet werden. Die Effektivität, mit der das in das Sediment eingetragene organische Material in mikrobielle Biomasse überführt wird, liegt zwischen 2 und 10%.

Observations on the microbial incorporation of thymidine and leucine in marine sediments

L.-A. Meyer-Reil and O. Charfreitag

Institut für Meereskunde an der Universität Kiel
Düsternbrooker Weg 20, D-2300 Kiel, Germany

Abstract

The simultaneous incorporation of radiolabelled thymidine and leucine was followed in intact muddy sand sediments from the North Sea. As it could be shown, incorporation activities covaried over sediment depth. Parallel analysis of the enzymatic decomposition of organic material (by means of the hydrolysis of fluoresceindiacetate) revealed that stimulations of microbial biomass production coincided with stimulations of enzymatic activities although maxima of both processes occurred at different sediment depths.

Introduction

To evaluate the role of microorganisms in mineralization processes and biomass production in marine sediments, measurements of microbial activity are essential. Of the various methods applied to estimate microbial activity, measurements of microbial biomass production seem to be most desirable since extrapolations on microbial growth rates may be derived. For the determination of microbial biomass production, the incorporation of radiolabelled thymidine into DNA and leucine into protein (FUHRMAN and AZAM 1982, KIRCHMAN et al. 1985) have been applied. Although a number of technical and conceptual problems exists (KIRCHMAN et al. 1986, McDONOUGH et al. 1986), the estimation of protein synthesis can complement estimates of DNA synthesis. As shown by CHIN-LEO and KIRCHMAN (1988) incorporation rates of leucine and thymidine covaried in marine microbial assemblages. We report here on observations of the simultaneous microbial incorporation of thymidine and leucine in marine sediments.

Material and methods

Cores were withdrawn using a multiple corer in August 1989 from a muddy sand sediment (water depth 35 m) located south of the island of Helgoland (North Sea). Intact subcores were taken in plexiglas tubes perforated at 0.5 cm intervals and sealed with silicone rubber. Through the ports 10 μ l of a mixture of 3 H-thymidine (90 Ci/mmol; final concentration 0.4 μ Ci) and 14 C-leucine (342 mCi/mmol; final concentration 0.024 μ Ci) were injected (for details of the core-injec-

Fine-scale distribution of hydrolytic activity associated with foraminiferans and bacteria in deep-sea sediments of the Norwegian-Greenland Sea

L.-A. Meyer-Reil and M. Köster

Institut für Meereskunde an der Universität Kiel
Düsternbrooker Weg 20, D-2300 Kiel, Germany

Abstract

Pronounced fine-scale gradients of enzymatic degradation of organic material were observed in the uppermost horizons of deep-sea sediments of the Norwegian-Greenland Sea. Since these gradients coincided with the occurrence of dense populations of epibenthic agglutinated foraminiferans, it was hypothesized that the foraminiferans were the main contributors to the large pool of hydrolytic enzymes observed. Parallel analyses of the enzymatic activity associated with individual foraminiferans selected from the sediments confirmed this hypothesis. Measurements of bacterial biomass (by epifluorescence microscopy) and production (incorporation of tritiated leucine) suggest that in the specific ecological situation analysed, bacteria benefit from the metabolism of foraminiferans rather than being the main decomposers. The immediate degradation at the sediment surface without incorporation of the sedimented particles into the sediment may have an impact on the early diagenesis of organic material and its sedimentary record in these deep-sea sediments.

Introduction

It seems to be generally accepted that the sedimentation of detrital material from euphotic waters represents the most important contribution to the nutrient supply of benthic communities in pelagic sediments (e.g. LOCHTE and TURLEY 1988, GRAF 1989). Very little is known, however, about the decomposition processes at the seafloor as well as about the organisms involved (JAHNKE and JACKSON 1987, GRAF 1989). Among these, a key role in the turnover of organic carbon is attributed to bacteria (ROWE and DEMING 1985) although foraminifera may be involved in carbon decomposition processes as well (GOODAY 1988, GOODAY and LAMBSHEAD 1989). Most of the organic material entering the sea floor is oxidized in surface sediment horizons by oxygen and eventually secondary oxidants (e.g. BENDER and HEGGIE 1984) at rates much more rapidly than it was previously thought (REIMERS and SMITH 1986, COLE et al. 1987).

We report here on observations of pronounced fine-scale gradients of enzymatic degradation of organic matter at the surface of deep-sea sediments of the Norwegian-Greenland Sea. These gradients coincided with the occurrence of dense

Microbial life in pelagic sediments: the impact of environmental parameters on enzymatic degradation of organic material

Lutz-Arend Meyer-Reil, Marion Köster

Institut für Meereskunde an der Universität Kiel, Abteilung Marine Mikrobiologie, Düsternbrooker Weg 20, W-2300 Kiel 1, Germany

ABSTRACT: The impact of environmental parameters, such as salinity, temperature, pressure, and nutrients, on microbial activity was investigated in pelagic sediments of the Norwegian-Greenland Sea (water depth between 1400 and 2000 m). As a general characteristic of benthic microbial activity, the enzymatic degradation of organic material, which represents the initial and rate-limiting step in carbon oxidation, was measured. For the enzymatic analysis, fluoresceindiacetate was used, a fluorogenic model substrate which is hydrolyzed non-specifically by hydrolytic enzymes. The substrate was added at saturation level, and potential enzymatic activity rates were derived from the slope of the linear part of time-dependent activity curves. From the investigations it can be concluded that the pool of hydrolytic enzymes in the pelagic sediments was not specifically adapted to ambient parameters such as salinity, temperature, and pressure. There was no indication of a psychrophilic and/or barophilic response. Enzymatic degradation of organic material was more regulated by the supply of organic material than by cold temperature and elevated pressure. Boiled detritus added to sediment cores incubated under *in situ* temperature on board ship caused an immediate stimulation of hydrolytic enzymes. The location of microorganisms in the sediment and the unique characteristics of microbial metabolism must both be considered as possible strategies for using the incoming organic material effectively and for surviving the long periods of nutrient deficiency in pelagic sediments.

INTRODUCTION

Compared to that in shallow-water sediments, microbial life in pelagic sediments is still under-investigated. This undoubtedly reflects the considerable logistical effort that is necessary to sample sediments in deeper waters. Furthermore, until recently the deeper regions of the seafloor attracted only limited scientific interest. Pelagic (deep-sea) sediments were understood as potentially hostile environments where low temperature, elevated pressure and low nutrient levels restricted microbial metabolic activity. During the last decade, however, the study of deeper waters (including sediments) has gained increasing attention, and extensive joint research programs have been established to study the parameters influencing the flow of organic material and microbial activity in the deep sea. Based on these studies, the conventional view of the seafloor as a nutrient-poor environment that continuously receives a low input of organic matter of low nutritional value (Jannasch 1979) had to be modified. It became

quite obvious that pelagic sediments are supplied with pulses of relatively fresh organic material via sedimentation from euphotic waters. Quantity and quality of the sedimented material were found to be subject to pronounced seasonal variations, which were reflected in the metabolic activity of the microbial assemblages (Lochte & Turley 1988, Graf 1989). Most of the organic matter oxidation occurred at the sediment surface and involved oxygen or possibly secondary oxidants (Bender & Heggie 1984). The metabolic rates measured were much more rapid than had been previously thought, considering the low temperature and elevated pressure (Deming 1986, Reimers & Smith 1986, Cole et al. 1987, Graf 1989). The regulation of microbial activity by temperature and pressure in the deep sea is still a matter of investigation. Although obligate barophilic bacteria have been cultured from deep-sea samples (cf. literature cited by Chastain & Yayanos 1991, Turley et al. 1988), the question still remains as to whether the degradation of organic material in the deep sea is governed by barophilic (and psychrophilic) responses.

BERICHTE

aus dem

SONDERFORSCHUNGSBEREICH 313

VERÄNDERUNGEN DER UMWELT - DER NÖRDLICHE NORDATLANTIK



Nr. 29

Sedimentation im Europäischen Nordmeer:

Radioisotopische, geochemische und tonmineralogische

Untersuchungen spätquartärer Ablagerungen

HANNO PAETSCH

7 Zusammenfassung

In der vorliegenden Arbeit wurden Oberflächensedimente und Sedimentkerne aus dem Europäischen Nordmeer geochemisch und mineralogisch bearbeitet. Die geochemischen Untersuchungen beinhalteten die Bestimmung von Radionukliden, die Bestimmung der Haupt- und Spurenelemente im Gesamtsediment und des Cd-Gehaltes in Foraminiferenschalen.

Die wichtigsten Ergebnisse dieser Untersuchungen sind:

- Die geochemische und tonmineralogische Zusammensetzung der Sedimente im Europäischen Nordmeer ermöglicht Rückschlüsse auf das Liefergebiet und die Transportwege des Sediments. So spiegeln erhöhte Montmorillonitgehalte, sowie erhöhte Mg/Al- und Ti/Al-Verhältnisse sowohl räumlich als auch zeitlich den Einfluß des Norwegenstroms wider. Erhöhte K/Al- bzw. Si/Al-Verhältnisse zeigen einen verstärkten Sedimenteintrag von den Kontinenten an.
- Die Radionuklidbestimmungen in den Oberflächensedimenten ermöglichen eine Quantifizierung des Sedimenteintrages im Europäischen Nordmeer. Dabei zeigt sich, daß der lithogene Partikelfluß aus dem Pelagial in weiten Bereichen des Europäischen Nordmeeres relativ konstant bei $750 \pm 200 \text{ mg} \cdot \text{cm}^{-2} \cdot \text{ka}^{-1}$ liegt.
- Die Variationen im $^{230}\text{Th}_{\text{ex}}$ -Tiefenprofil, die für die Gebiete hoher Breiten typisch sind, sind zum größten Teil auf unterschiedliche Verdünnung und nur zu einem kleineren Teil auf Sediment focusing oder Winnowing zurückzuführen. Andere Prozesse haben keinen Einfluß auf die $^{230}\text{Th}_{\text{ex}}$ -Verteilung im Sediment.
- Für die Datierung von Sedimentkernen aus dem Europäischen Nordmeer wird eine Kombination aus $^{230}\text{Th}_{\text{ex}}$ -Stratigraphie und constant-flux Modell vorgeschlagen.
- Durch die Kombination verschiedener geochemischer und mineralogischer Untersuchungsmethoden in Sedimentkernen der Norwegischen See wurde versucht, die paläozeanographische Entwicklung während der Termination II zu rekonstruieren. Es zeigte sich als wichtigstes Ergebnis, daß die Tiefenwasserneubildung in der Norwegischen See erst 5.000 bis 10.000 Jahre nach dem Wiedererstarren des Norwegenstromes einsetzte.
- Der bearbeitete Sedimentkern aus der Grönländischen See ist gekennzeichnet durch eine strömungskontrollierte Sedimentation. Veränderungen in den Strömungsbedingungen zeigen hier eine deutliche Abhängigkeit von den Klimazyklen.

Accumulation rates of surface sediments in the Norwegian–Greenland Sea

H. Paetsch, R. Botz, J.C. Scholten and P. Stoffers

Geologisch-Paläontologisches Institut und Museum der Universität Kiel, Olshausenstrasse 40, 2300 Kiel, Germany

(Received March 6, 1991; revision accepted June 25, 1991)

ABSTRACT

Paetsch, H., Botz, R., Scholten, J.C. and Stoffers, P., 1992. Accumulation rates of surface sediments in the Norwegian–Greenland Sea. *Mar. Geol.*, 104: 19–30.

Assuming a constant flux of ^{230}Th to the sediment, surface, accumulation and sedimentation rates of surface sediments in the Norwegian–Greenland Sea have been calculated. The accumulation rates range from 0.7 to 4.0 $\text{g cm}^{-2} \text{ ka}^{-1}$, and the sedimentation rates range from 0.87 to 6.58 cm ka^{-1} . Applying a simple box model it can be shown that the effects of bioturbation on the calculation are of minor importance for the area studied.

The input of biological material indicated by the flux of CaCO_3 is the highest (up to 1.2 $\text{g cm}^{-2} \text{ ka}^{-1}$) in areas influenced by the Norwegian Current, whereas in the Southern Greenland Sea the flux of CaCO_3 is one order of magnitude lower.

The pattern of the terrigenous input calculated by the difference between bulk sediment and CaCO_3 flux reflects the importance of the Norwegian continent, the Greenland continent and the island Jan Mayen as source areas for terrigenous matter delivered to the Norwegian–Greenland Sea.

Introduction

Quantitative sedimentation models rely on the accurate determination of sediment fluxes. During the past, transport mechanisms of various sediment components (particles, major and trace elements, radionuclides) have been studied in order to determine accumulation rates of either selected sediment components or bulk sediment (Thiede et al., 1982; Schmitz et al., 1986). In particular, radionuclides (^{210}Pb , ^{230}Th , ^{234}U , ^{231}Pa , ^{10}Be , etc.) have been measured in the water column, in sediment traps and in the sediment in order to quantify sediment fluxes (Bacon et al., 1985, 1989).

The radionuclide ^{230}Th is produced at a constant rate within the water column (2.63 $\text{dpm cm}^{-2} \text{ ka}^{-1}/1000 \text{ m}$ of water; Bacon, 1984) by the radioactive decay of ^{234}U (Ku, 1965). As thorium is strongly particle-reactive, its mean residence time in seawater is short (30–40 years; Ku, 1976; Bacon and Anderson, 1982; Bacon, 1984). Hence it is assumed that ^{230}Th , after being produced in the

water column, is rapidly transported into the sediments below this column (Suman and Bacon, 1989). However, under certain circumstances (e.g. sediment erosion or focussing) the calculated ^{230}Th flux based on sediment ^{230}Th activities is lower (in the case of sediment erosion) or higher (in the case of sediment focussing) than the “expected” ^{230}Th flux (calculation based on the production in the water column) (Mangini, 1984). The aim of the present study is to quantify recent sedimentation processes in the Norwegian–Greenland Sea by applying the constant flux model of ^{230}Th on surface sediments of the region.

Material and methods

Sediment cores were taken from the Norwegian–Greenland Sea (Fig. 1) as part of the activities of the “Sonderforschungsbereich 313, Sedimentation in the Norwegian–Greenland Sea” at Kiel University, Germany. For the present study 44 macro-

$^{230}\text{Th}_{\text{ex}}$ FLUX INTO NORWEGIAN-GREENLAND SEA SEDIMENTS: EVIDENCE FOR
LATERAL SEDIMENT TRANSPORT DURING THE PAST 300,000 years

J. Scholten; R. Botz; H. Paetsch & P. Stoffers

Abstract

^{230}Th was determined to investigate the influence of climatic cycles on the $^{230}\text{Th}_{\text{ex}}$ flux into Norwegian-Greenland Sea sediments. The Fa/Fp ratios, i. e. the ratios between the measured $^{230}\text{Th}_{\text{ex}}$ flux (Fa) into the sediments and the production rate of ^{230}Th in the water column (Fp), vary considerably in the four cores investigated. There were no systematic variations of the ratio with the climatic cycles to be observed. Furthermore, variations in the Fa/Fp ratios cannot be correlated from core to core.

Lateral sediment transport, which is due to bottom currents and down slope sediment transport, is likely to be responsible for Fa/Fp ratios different from 1. The results suggest that sediment winnowing (and/or erosion) and sediment focusing have a major influence upon sediment accumulation in the Norwegian-Greenland Sea.

Introduction

The distribution of natural radionuclides in both water masses and related sediments is of major importance in evaluating fluxes of sedimentary components in the ocean [1]. studies on the distribution of ^{230}Th (half life $T_{1/2}=75,200$) in the marine environment, for instance, resulted in most useful sedimentation models for the last 300.000 years [2,3,4]. ^{230}Th is

"STATE-OF-THE-ART" RADIOACTIVE DATING OF HIGH LATITUDE
(NORWEGIAN-GREENLAND SEA) SEDIMENTS: ^{230}Th VS. $\delta^{18}\text{O}$ STRATIGRAPHY

J.C. Scholten^{*}; R. Botz[†]; H. Paetsch^{*}; P. Stoffers^{*} & M. Weinelt[‡]

^{*}Geologisch-Paläontologisches Institut und Museum, Universität
Kiel, 2300 Kiel, Germany

[†]GCA-Geochemische Analysen, 3160 Lehrte, Germany

[‡]SFB 313, Universität Kiel, 2300 Kiel, Germany

Abstract

The ages of four long sediment cores from the Norwegian-Greenland Sea were determined by using various ^{230}Th dating models. The results were then related to an independent time control ($\delta^{18}\text{O}$) which was available for the cores under consideration. Average sedimentation rates were calculated from $^{230}\text{Th}_x$ vs. depth profiles. These rates are similar to rates obtained by the $\delta^{18}\text{O}$ stratigraphy (if the cores cover the past 300,000 years). Furthermore, average sedimentation rates can also be determined by a $^{230}\text{Th}_x$ stratigraphy.

A high time resolution is achieved for sediment cores which are not influenced by lateral sediment transport by a ^{230}Th constant-flux model. A powerful tool for chronostratigraphic studies of (carbonate-poor) sediment cores appears to be the combination of ^{230}Th measurements and $\delta^{18}\text{O}$ stratigraphy which allows the determination of individual sedimentation rates for each core layer.

Introduction

Ocean sediments give information on the paleoclimatic evolution in the geological past. The oxygen isotope composition of calcareous foraminifera depends on climatic conditions and can

[FB]

High resolution $^{230}\text{Th}_{\text{ex}}$ stratigraphy of sediments from high-latitude areas (Norwegian Sea, Fram Strait)

Jan C. Scholten ^a, Reiner Botz ^a, Augusto Mangini ^b, Hanno Paetsch ^a, Peter Stoffers ^a
and Elke Vogelsang ^a

^a *Geologisch-Paläontologisches Institut und Museum, Universität Kiel, 2300 Kiel, F.R.G.*

^b *Heidelberger Akademie der Wissenschaften, 6900 Heidelberg, F.R.G.*

Received January 4, 1990; revised version accepted May 28, 1990

ABSTRACT

We present data on the average sedimentation rates (ranging from 1.6 cm/kyr to 3 cm/kyr) for the last 300,000 years based on $\delta^{18}\text{O}$ analyses of foraminifera in a core from the Norwegian Sea and $^{230}\text{Th}_{\text{ex}}$ measurements in cores from the Norwegian Sea and the Fram Strait (Arctic Ocean). Furthermore, we relate $^{230}\text{Th}_{\text{ex}}$ variations downcore to the various oxygen isotope stages. This correlation is tentatively interpreted as being a result of the paleoceanographic and paleoclimatic control of bioproductivity. It is shown that based on the average sedimentation rates and characteristic $^{230}\text{Th}_{\text{ex}}$ variations carbonate-poor sediment cores from northern latitudes can be correlated.

1. Introduction

Recently, much attention has been paid to the paleoceanographic and paleoclimatic record of sediments recovered from oceans world-wide. Stable-isotope stratigraphy gives detailed information on both the age of the sediments and the paleoceanographic and paleoclimatic conditions during sedimentation [1–3]. This technique is generally restricted to carbonate-(foraminifera)-containing sediments from low latitudes. High-latitude sediments usually lack carbonate matter due to the comparatively low organic productivity under cold (with variable salinities) water conditions. Therefore $\delta^{18}\text{O}$ records of long sediment cores from high latitudes are scarce, and other similarly powerful dating techniques for non-calcareous sediments are yet to be developed.

One possible way to date sediments is with the ^{230}Th excess ($^{230}\text{Th}_{\text{ex}}$, non-supported ^{230}Th in sediments) method which can be used to date sediments up to 300,000 years old [4–6]. This method relies on a constant flux of $^{230}\text{Th}_{\text{ex}}$ to the seafloor, where the radionuclide is deposited on

the sediment surface. With increasing sediment age the $^{230}\text{Th}_{\text{ex}}$ concentration decreases with a half-life of 75,200 years. As a consequence, average sedimentation rates can be calculated.

In order to overcome the chrono-stratigraphic problems in sediments of high latitudes, we have measured the $^{230}\text{Th}_{\text{ex}}$ concentration profile of core 23059 (70°25.4'N; 4°1.3'E; 2281 m water depth) and compared the results with the $\delta^{18}\text{O}$ record of the core.

2. Methods

The sediment core was collected during R/V *Meteor 2/2* cruise (1986, Fig. 1). The core consists of continuously deposited sediments which have been investigated in detail for paleoceanographic purposes [7,8]. These studies also included measurements of $\delta^{18}\text{O}$ in planktonic foraminifera, which yielded a high-resolution stratigraphy for the Norwegian Sea. For $^{230}\text{Th}_{\text{ex}}$ measurements in core 23059, sediment samples were taken continuously (each sample represents a homogenized 5–10 cm sediment slice) and prepared by chemical sep-

Teilprojekt B1:

GEOPHYSIKALISCHE SIGNALE IN SEDIMENTEN

Kurzfassungen

Der im SPS 313 verwendete HF-OES (Frequenzbereich 1 kHz - 10 kHz) hat zum Ziel die P-Wellengeschwindigkeit der ersten 10 m Sedimente mit einer maximal erreichbaren Auflösung zu bestimmen. Während die Meeresfläche und der OES unterhalb einer piezoelektrischen akustischen Quelle nacheinander über dem Meeresboden ausgeföhrt. Danach entfernt sich die Quelle von dem OES, bis ca. 20 m über dem Meeresgrund mittels eines Einheitsdrucks geschoben wird, während die im Sediment akustische Signale ausstrahlen. Diese Signale durchlaufen die verschiedenen Sedimentschichten, werden reflektiert und dann von dem OES digital aufgezeichnet.

Die durch den variablen Offset (Entfernung Quelle - Empfänger) in den Seismogrammen erzielten unterschiedlichen Reflexionshyperecho werden zur Bestimmung der Intervallgeschwindigkeit benutzt (Normal-Move-Out-Korrektur in der Reflexionsseismik).

Die Bestimmung der P-Wellengeschwindigkeit ist wichtig um:

- a) gasungesättigte Sedimente näher zu untersuchen und zu beschreiben,
- b) in Seismogrammen Laufzeiten in wasser Tiefe umzuschreiben.

Zudem können aufgrund der digitalen Daten Impedanzkurven berechnet werden. Erste Anzeichen, dass Impedanzkurven innerhalb der oberen Sedimente mit klimabedingten Veränderungen korrelieren, konnte bereits mit Hilfe von Kern-Logger-Daten (CNC) nachgewiesen werden.

DGG, Kiel, 1993

M. Bobsien (SFB 313), J. Mienert (GEOMAR, Kiel)

Entwicklung und Einsatz eines HF - Ozean - Boden - Seismographen zur Bestimmung von P - Wellen geschwindigkeiten

Der am SFB 313 entwickelte HF-OBS (Frequenzbereich 1 kHz - 10 kHz) hat zum Ziel, die P-Wellengeschwindigkeit der oberen 100 m Sedimente mit der maximal erreichbaren Auflösung zu bestimmen. Während des Meßeinsatzes wird der OBS unterhalb einer piezoelektrischen akustischen Quelle hängend direkt über dem Meeresboden ausgeklinkt. Danach entfernt sich die Quelle von dem OBS, die ca. 20 m über dem Meeresgrund mittels eines Einleiterdrahtes geschleppt wird, während sie im Sekundentakt akustische Signale aussendet. Diese Signale durchlaufen die verschiedenen Sedimentschichten, werden reflektiert und dann von dem OBS digital aufgezeichnet.

Die durch den variablen Offset (Entfernung Quelle - Empfänger) in den Seismogrammontagen entstehenden Reflexionshyperbeln werden zur Bestimmung der Intervallgeschwindigkeiten benutzt (Normal-Move-Out-Korrektur in der Reflexionsseismik).

Die Bestimmung der P-Wellengeschwindigkeit ist wichtig um:

- a) gasangereicherte Sedimente näher zu untersuchen und zu beschreiben;
- b) in Seismogrammen Laufzeiten in wahre Tiefe umzurechnen.

Zudem können aufgrund der digitalen Daten Impedanzkurven berechnet werden. Erste Ansätze, daß Impedanzkurven innerhalb der oberen Sedimente mit klimabedingten Veränderungen korrelieren, konnte bereits mit Hilfe von Kern-Logger-Daten (Chi; Mienert) gezeigt werden.

J. Chi (SFB 313, Kiel), J. Mienert (GEOMAR, Kiel)

Physikalischer Meeresbodenaufbau: Eine Zeitreihenanalyse orbitaler Zyklen anhand von "Multi-Sensor-Kern-Logging" Daten

Der Multi-Sensor-Kern-Logger (MSKL) mißt drei physikalische Sedimenteigenschaften während der automatisch gesteuerten Vorwärtsbewegung der Sedimentkerne (Abb. 1): (1) die Laufzeit eines akustischen Signals transversal durch die Probe, aus der die Kompressionswellengeschwindigkeit berechnet wird; (2) die Zählrate (γ -Quelle ^{137}CS) nach der Abschwächung durch das Sediment, welche anschließend auf Feuchtdichte, Porosität und Wassergehalt umgerechnet werden kann; (3) die magnetische Suszeptibilität. Damit können entlang von Sedimentkernen die Kompressionswellengeschwindigkeit, die Dichte und die magnetische Suszeptibilität für jedes Intervall (cm-Bereich), das einer bestimmten Sedimenttiefe entspricht, im zerstörungsfreien Meßverfahren bestimmt werden.

Die magnetische Suszeptibilität und die Kompressionswellengeschwindigkeit werden direkt gemessen, die Feuchtdichte wird dagegen indirekt über das Schwächungsgesetz für Röntgen- und γ -Strahlung ermittelt. Aus diesem Grund wurde für die Kalibrierung der Dichtemessung mit Aluminium, Quarzsand und Sedimenten der Massenschwächungskoeffizient exakt für Sedimente bestimmt. Dabei wurden die vom MSKL gemessenen Dichtedaten mit den manuell berechneten Meßwerten desselben Sedimentkerns kalibriert (Abb. 2). Die so gewonnene Kalibrierung wurde durch eine zweite Vergleichsmessung mit einem weiteren Kern überprüft und die Genauigkeit bestätigt (Abb. 3). Neben den oben genannten drei Meßgrößen werden noch die Korrektur des Liner-Durchmessers (ΔD in der Darstellung) und die Amplitude des empfangenen akustischen Signals zur Qualitätskontrolle der Schallgeschwindigkeitsmessung mit registriert. Zur Qualitätskontrolle dient auch die Korrelation zwischen der Dichte und der Schallgeschwindigkeit. Im nächsten Schritt wird aus der Kompressionswellen-geschwindigkeit und Dichte ein synthetisches Seismogramm berechnet und mit der Parasound-Aufzeichnung verknüpft, um die punktförmigen sedimentphysikalischen Informationen mit Hilfe der Parasound-Profile in den Raum zu übertragen (Abb. 4). Um für die Logging-Daten eine indirekte Alterseinstufung durchzuführen (Abb. 5), wurde die zeitgeichete SPECMAP- ^{18}O -Kurve mit dem Karbonatgehalt sowie der magnetischen Suszeptibilität korreliert. Eine Zeitreihenanalyse anhand dieser Daten soll die orbitalen Einflüsse auf die Sedimentation bestimmen. Zwei Beispiele vom Rockall Plateau werden hier präsentiert (Abb. 6).

POSTER

TERTIARY SEA LEVEL CHANGES ON ICELAND-FAEROE RIDGE

Ch. Krawczyk (GEOMAR, Kiel, Germany), A. Omlin and F. Theilen

The Iceland-Faeroe Ridge was formed in Paleocene and Eocene during the opening of the Northeast-Atlantic. It prevented the free exchange of water masses between the Iceland Basin and the Norwegian-Greenland Sea in the Early Tertiary.

The subsequent thermal subsidence of the Iceland-Faeroe Ridge is documented in the sedimentary structures investigated by high-resolution reflection seismic measurements. The correlation with geological epochs is given by DSDP site 336, leg 38, where all sequences except Miocene have been observed. This prominent hiatus is mapped at the upper part of the ridge while a sedimentary sequence of probably Miocene age has been found further downslope to the Norwegian-Greenland Sea.

The Eocene sediments are characterized by a high degree of transparency. Nevertheless, some internal reflectors can be recognized. A series of parallel reflectors is visible above the basaltic basement, partly overlain by foreset beds. This might indicate the onset of sea-level changes at the northern flank of the Iceland-Faeroe Ridge already during Eocene.

The East Greenland continental margin (65°N) since the last deglaciation: Changes in seafloor properties and ocean circulation

Jürgen Mienert,^a John T. Andrews^b and John D. Milliman^c

^a*GEOMAR, Forschungszentrum für Marine Geowissenschaften der Christian-Albrechts-Universität, Wischhofstr. 1-3, Kiel, Germany*

^b*Institute of Arctic and Alpine Research and Department of Geological Sciences, University of Colorado, 1560 30th Street, Boulder, CO 80309, USA*

^c*Woods Hole Oceanographic Institution, Woods Hole, MA 02543, USA*

(Received September 13, 1990; revision accepted October 30, 1991)

ABSTRACT

Mienert, J., Andrews, J.T. and Milliman, J.D., 1992. The East Greenland continental margin (65°N) since the last deglaciation: Changes in seafloor properties and ocean circulation. *Mar. Geol.*, 106: 217-238.

Nine gravity cores collected on the East Greenland continental margin off Kangerdlugssuaq Fjord reveal a drastic decrease in average sedimentation rates from the cross-shelf trough to the continental slope (from 43.2 cm/kyrs to 2.2 cm/kyrs, respectively). Since the last deglaciation, beginning at < 15,000 yrs B.P., both carbonate and non-carbonate accumulation rates have been controlled by the decrease in glaciers and sea ice and the increase in surface-water circulation. CaCO₃ and non-CaCO₃ accumulation rates at about 14,000 yrs B.P. were high on the outer shelf, followed by high values at the inner shelf about 9000 yrs B.P., suggestive of rapid glacier retreat. About 9000 yrs B.P., the northerly flowing Irminger Current and the southerly flowing East Greenland Current may have increased intensity leading to distinct increases in CaCO₃ accumulation (> 2 g/cm²kyrs). At 4000 yrs B.P., both CaCO₃ and non-CaCO₃ accumulation rates became high (< 10 g/cm²kyrs); since 3000 yrs B.P. these rates distinctly decreased. Melting of glaciers and current activity, which drastically changed in space and time, controlled the terrigenous sediment input, and thus the grain-size distribution and the physical properties of sediments, across the shelf. These observations suggest that current winnowing on sediments is one of the dominant processes at present. This is seen in the acoustic reflectivity and in the acoustically hard seafloor, particularly at the upper continental slope. In addition, icebergs transported southward along the continental margin, have scoured the sediment surface in water depths < 350 m.

ORAL

FURROWED SEDIMENT WAVES ON THE BARENTS SEA CONTINENTAL SLOPE

J. Mienert (GEOMAR, Kiel, Germany) and M. Bobsien (SFB 313)

A deep-towed sidescan sonar and 3.5 kHz survey of the Barents Sea continental slope (75°N, 12°W) mapped several types of bedforms. They are sediment waves, furrows and sediment slides which may shed light on the occurrence and interaction of a number of processes. Previous studies of continental slopes in the Atlantic show that sediment waves tend to occur at about 4500 m water depth along the slope, but little is known about their origin. We discovered buried and exposed sediment wave like features that clearly occur within approximately 1.5 km wide and several km long lobes of a slide complex at 2500 m water depth. The wave troughs tilt towards the slide complex indicating slump faults. On top of these wave like features preferential sedimentation occurs, which may be attributed to a directed sediment transport by bottom water currents. Thus we anticipate that the primary origin of the sediment waves is caused by an instability event of the slope and the secondary feature shown in the upper few meters of the sediment is contour current controlled. This hypothesis is supported by the occurrence of furrows that are aligned towards 340 almost parallel to the 2450 m contour. Most of these furrows are parallel and as much as 10 to 40 m apart, possibly several tens of kilometer long and 1 to 4 m deep. While they cover an area of about 300 km² their spacing decreases towards the 2500 m isobath line.

The furrows appear to parallel the direction of the warm northward flowing Norwegian Current. The distribution and sedimentation of these furrows and sediment waves may correlate with variations in current strength across the continental slope. At the present time the site is exposed to variable current speeds but furrow erosion and sediment wave deposition may provide a long term record of the Norwegian Current activity if calibrated by current flow meters.

F6. Paleo-oceanography of the North Atlantic region

26 J. Mienert (GEOMAR, Kiel, F.R.G.), F.-J. Hollender (SFB 313, Kiel, F.R.G.), N. Kenyon (Institute of Ocean Sciences, Wormley, U.K.)

POLAR MARGINS: GLORIA STUDIES OFF EAST GREENLAND FROM 70° TO 80° NORTH

GLORIA, the I.O.S. long range side scan sonar, has been used in 1992 on a RV Livonia cruise to map large scale changes in sediment patterns and deduct from it the sedimentary processes along the East Greenland continental margin. During this cruise we produced a side scan sonar coverage of the complete Greenland basin and margin to a total area of about 250.000 km². The Boreas basin, the East Greenland basin and a small basin just north of Jan Mayen Fracture Zone are one of the keys to the understanding of the glacially influenced margins. Sedimentary features of the three basins give them a strikingly different appearance. Based on the preliminary interpretation of the GLORIA sonographs we may conclude that: (1) little direct evidence for along slope transport of sediments have been found along the East Greenland margin and basin investigated, (2) in contrast, strong evidence exists for down slope transport processes in the Greenland basin, (3) sediment wave fields may indicate the processes of bottom water current or turbidity current activity at specific site locations, (4) circular high back scatter regions give hints of large areas of gas venting which needs to be ground truthed by coring and seismic studies, (5) there exists a large contrast to the Norwegian margin in that the Norwegian margin exhibits wide areas of sediment slide complexes that were not observed on the East Greenland margin.

DGG, Kiel, 1993

J. Mienert (GEOMAR, SFB 313, Kiel), F.-J. Hollender (SFB 313, Kiel) and N. Kanyon (Institute of Ocean Sciences, Wormley, U.K.)

GLORIA STUDIES OF POLAR MARGINS: EAST GREENLAND FROM 70° TO 80° NORTH

GLORIA, the I.O.S. long range side scan sonar, has been used in 1992 on a RV Livonia cruise to map large scale changes in sediment patterns and deduct from it the sedimentary processes along the East Greenland continental margin (J. Mienert & N. Kanyon, 1992). During this cruise we produced a side scan sonar coverage of the complete Greenland basin and margin to a total area of about 250.000 km². The working area is permanently hindered by sea ice apart for the period from August to September when sea ice starts to melt and decays towards the shelf edge. During this period of time GLORIA made its first survey to the polar regions of the East Greenland margin.

Transform ridges divide the area between Fram Strait and Jan Mayen into three basins. These are from north to south, the small NW-SE oriented 3200 m deep Boreas basin, the large NE-SW aligned 3600 m deep East Greenland basin, and the small E-W oriented 2400 m deep basin just north of Jan Mayen Fracture Zone. The three basins are one of the keys to the understanding of the glacially influenced margins. Sedimentary features of the three basins give them a strikingly different appearance. Based on the preliminary interpretation of the GLORIA sonographs we may conclude that: (1) little direct evidence for along slope transport of sediments have been found along the East Greenland margin and basin investigated, (2) in contrast, strong evidence exists for down slope transport processes in the Greenland basin, (3) sediment wave fields may indicate the processes of bottom water current or turbidity current activity at specific site locations, (4) circular high back scatter regions give hints of large areas of gas venting which needs to be ground truthed by coring and seismic studies, (5) there exists a large contrast to the Norwegian margin in that the Norwegian margin exhibits wide areas of sediment slide complexes that were not observed on the East Greenland margin.

PHYSIOGRAPHY OF POLAR CONTINENTAL MARGINS: GLORIA STUDIES OFF EAST GREENLAND FROM 70° TO 80 ° NORTH

J. Mienert^{1,2}, N. Kenyon³, J. Thiede^{1,2} and F.-J. Hollender²

¹ GEOMAR, Forschungszentrum für marine Geowissenschaften der Christian-Albrechts-Universität zu Kiel, Wischhofstr. 1-3, D-2300 Kiel 14, F.R.G.

² Sonderforschungsbereich 313 (SFB 313) der Christian-Albrechts-Universität zu Kiel, Olshausenstr. 40-60, D-2300 Kiel 14, F.R.G.

³ Institute of Ocean Sciences (IOS), Brook Road, Wormley, Godalming, Surrey, GU8 5UB, U.K.

The passive continental margin off East Greenland has been shaped by tectonic and sedimentary processes. Typical physiographic trades have evolved over the past few million years under the influence of the late Cenozoic northern hemisphere glaciations, in particular the Greenland ice shield.

GLORIA, the I.O.S. (Institute of Ocean Sciences) long range side scan sonar, has been used in 1992 on a RV Livonia cruise to map large scale changes in sedimentary patterns along the East Greenland continental margin. The overall objective of this research programme was to determine the variety of large scale sea floor processes in order to improve our understanding of the interaction between ice sheets, current regimes and sedimentary processes. In co-operation with the Institute of Oceanographic Sciences (IOS), Wormley (U.K.) and the RV Livonia from Tallinn (Estonia) a high quality set of sea floor data has been produced. GLORIA's first survey to the polar regions of the East Greenland continental margin covered several 1000 km long and 50 km wide track lines (Figure 1) and as a result an impressive side scan sonar image of the complete Greenland Basin and margin (about 250.000 km²). Based on our GLORIA tracks a mosaic of the data was made at a scale of 1:375,000. The base map was prepared with a Polar Stereographic Projection having a standard parallel of 71 degrees.

The working area (Figure 2) is permanently covered by sea ice apart for the period from August to September when sea ice starts to melt and decay and when its eastern margin relocates towards the shelf edge. Along this margin southward flowing currents such as the East Greenland Current (EGC) are carrying cold water masses from the Arctic Ocean through the Denmark Strait into the North Atlantic. While these currents may cause vigorous along slope transport of sediments the calving of glaciers from the Greenland ice sheet and melt water may entrain large amounts of sediments, which are carried across the shelf and finally deposited in the deep sea by gravity flows. This highly dynamic system appears to be very sensitive to changes in ice sheets extent and current activities which are driven by changes in northern hemisphere climate. Certainly, East Greenland is one of our best analogues for "glacial" polar

PHYSICAL AND ACOUSTIC PROPERTIES OF ARCTIC OCEAN DEEP - SEA
SEDIMENTS: PALEOCLIMATIC IMPLICATIONS

J. MIENERT¹, L. A. MAYER², G. A. JONES³, and J. W. KING⁴

¹GEOMAR, Forschungszentrum für Marine Geowissenschaften
Wischhofstraße 1-3
D-2300 Kiel 14, F.R.Germany

²Dalhousie University
Department of Oceanography
Halifax, Nova Scotia, B3H4J1, Canada

³Woods Hole Oceanographic Institution
Woods Hole, Ma 02543, U.S.A.

⁴University of Rhode Island
Graduate School of Oceanography
Narragansett, RI 02882-1197, U.S.A.

ABSTRACT. Six sediment cores from the Eurasian Basin were studied to determine and understand climatically driven changes of Arctic Ocean basins. Detailed time control of sediments for the last 45 kyr is based on accelerator mass spectrometry (AMS) C14-dating of biogenic carbonate (*N. pachyderma*, left coiling). The most important results from our study are summarized as follows. From 45 to 13.5 ka low sedimentation rates prevailed (0.35 cm/kyr). They increased drastically at the transition from the last glacial to interglacial (Termination Ia, 13.5 ka) leading into high Holocene sedimentation rates (1.06 cm/kyr). Low carbonate concentrations (< 4%) prevailed from 13.5 to 9 ka at Termination I. Decreased salinities can be expected for Termination Ia (Zahn *et al.*, 1985, Jones & Keigwin, 1988, Mienert *et al.*, 1989) due to glacial meltwater influence possibly accompanied by sea ice melting. As a result of the freshwater influence, productivity of planktic foraminifers decreased and this, in turn, resulted in a drastic decrease in carbonate concentration during Termination Ia. Although carbonate concentration varies only between 0 and 9%, it distinctly changes both the compressional-wave velocity (from 1485 to 1510 m/s) and the wave attenuation (from 0.1 to 0.45 dB/m/kHz) in the sediment. Climatically driven changes in magnetic susceptibility have proved to be a valuable paleoclimatic tool for intercore correlations. Our results indicate that the same general conclusions are valid for pelagic environments of both Atlantic and Arctic Ocean basins.

POSTER

SUBSIDENCE AND SEDIMENTARY HISTORY SOUTH-WEST OF THE FAEROE ISLANDS

J. Posewang (Institute of Geophysics, Kiel University, Germany) and Fr. Theilen

The evolution of the area southwest of the Faeroe Islands has mainly be influenced by massive volcanic extrusions in Late Paleocene. Lavaflows propagated from the Faeroe Islands in southwesterly direction. They are now covered by sediments of Eocene age and younger.

During the Eocene a number of seamounts, intrusive and extrusive centres developed in this area. Reflection seismic have been carried out on two of these features: The Bill Bailey and the Lousy Bank. Seismic data show two lavaflows of different origin and flow direction below the Lousy Bank, which is suggested to be an extrusive centre.

The analysis of the sedimentary structures reveals that the top of the banks are void of sediment. Deposition is concentrated in the trough between the two banks and the surrounding areas. Onlap structures evidence the crustal subsidence between the banks, erosional horizons mark sea level changes and downlap structures document the direction of sedimentation and changes in sediment transport within this region due to the subsidence of the Iceland-Faeroe Ridge. The transition between the banks and the Iceland-Faeroe Ridge is characterized by a thin cover of sediments and a small trough associated with the Faeroe Bank Channel.

GLORIA SIDE-SCAN SONAR MOSAIC OF THE EAST GREENLAND CONTINENTAL MARGIN FROM 70° TO 80° NORTH

The technique and interpretation of side scan sonar was pioneered at IOS (Institute of Oceanographic Sciences, Deacon Laboratory, Wormley, U.K.) (Somers, M. L., et al., 1978). The transducer of GLORIA, the long range side scan sonar has 2 rows with 30 elements each, it works with a horizontal angular beam width of 2.5_«symbol» and a vertical angular beam width of 30_«symbol». The operating frequency is 6.2 to 6.8 kHz, the peak electrical power is 12 kW per side and the peak power into the water is 10.5 kW per side. The range is from 7 to 30 km on each side. GLORIA is 7.75 meters long and has a diameter of 0.66 meters, the length of the active part is 5.33 meters, the total weight of the vehicle in air is 2.04 tonnes, the overall weight including cable, power pack, etc. is 13 tonnes. It is towed 400 meters behind the survey ship at a speed of up to 10 knots and a nominal depth of 50 meters. The output of GLORIA data was stored on magnetic tape in a digital format and on-line on analogous images from which we produced the side-scan sonar mosaic (Fig. xx).

On the cruise with the RV Livonia in 1992 GLORIA the long range side scan sonar has been used to map large scale changes in sedimentary pattern along the East Greenland continental margin. The goal of the cruise was to determine the variety of large scale sea floor processes in order to improve our understanding of the interaction between ice sheets, current regimes and sedimentary processes. The working area encompassed the Fram Strait, the Boreas Basin, the Greenland Basin and a small basin just north of the Jan Mayen fracture zone. The area is permanently covered by sea ice, only from August to September the sea ice starts to melt and removes towards the shelf edge.

The Boreas Basin has a very uniform medium to low level backscatter apart from a single weakly backscattering feature that looks like a channel. This channel is discontinuous and is thus believed to be inactive and perhaps filled by a fine grained abandonment facies (Mienert et al., 1993). In all sonograph images of this area is an outstanding acoustic artefact, it is believed to be interference fringes caused by multiple paths taken through the uppermost layers of soft sediment. Therefore penetrates into the sea floor and this implies that the sediment layers have different acoustic properties and are fine grained. We also find circular patches of high backscatter some of them has a positive relief, the patches are equidimensional and up to half a kilometer across. They might be indicative of gas venting and show some kind of gas venting feature such as pockmarks and hard grounds.

The Greenland Basin shows a variety of backscattering where the overall backscatter level is much higher than that of the Boreas Basin. In the south there are four channel systems whereas in the north there are no channel systems. In the north the shelf is at its widest and is believed to

Short term processes and patterns in the foraminiferal response to organic flux rates

A.V. Altenbach

Geologisch-Paläontologisches Institut, Olshausenstr. 40, 2300 Kiel, Germany

(Revision accepted November 9, 1991)

ABSTRACT

Altenbach, A.V., 1992. Short term processes and patterns in the foraminiferal response to organic flux rates. In: G.J. van der Zwaan, F.J. Jorissen and W.J. Zachariasse (Editors), Approaches to Paleoproductivity Reconstructions. *Mar. Micropaleontol.*, 19: 119-129.

The measurement of the benthic response to the input of organic matter derived from the photic zone gives insight into the relationship between sea surface productivity and growth, reproduction and population fluctuations of benthic foraminifera. At Kieler Bucht (Kiel Bight), biomass and reproduction cycles of *Elphidium excavatum clavatum* are directly related to the development and sedimentation of phytoplankton biomass over the entire year. Deep-sea foraminifera from the Norwegian Sea fed in a microcosm show a lag time of food ingestion and growth rates quite similar to what has been observed in shallow water communities. In response to the food pulse, *Cribrostomoides subglobosum* nearly doubled individual bodymass (org. C) over a period of 72 hours by ingestion of organic matter into food vacuoles. In both studies, approximately 6 to 10% of the total organic flux arriving on the sediment surface is ingested by benthic foraminifera, indicating that foraminifera play an important role in the cycling of organic matter in marine benthic environments.

Henning A. Bauch (1993): Planktische Foraminiferen im Europäischen Nordmeer: ihre Bedeutung für die paläo-ozeanographische Interpretation während der letzten 600.000 Jahre

ZUSAMMENFASSUNG

Quantitative und biometrische Untersuchungen an planktischen Foraminiferen sowie die Bestimmung der Artenzusammensetzung ihrer Gemeinschaft wurden an Sedimentkernen aus dem Europäischen Nordmeer durchgeführt. Die Ergebnisse wurden für die zeitliche und räumliche Konstruktion der paläo-ozeanographischen Entwicklung herangezogen. Mithilfe der O-Isotopenstratigraphie konnten die Veränderungen von Verbreitungsmuster einzelner Arten und ihre Beziehung zu spezifischen Wassermassen erkannt werden. Die Fluktuationen der Faunenzusammensetzung sind dabei primär eine Reaktion auf veränderte Lebensbedingungen, wobei subpolare und polare Arten in Abhängigkeit zum Einfluß einströmender atlantischer Wassermassen und dem daraus entstehenden Zirkulationssystem stehen.

Die Konzentrationen der subpolaren Art *Globigerina quinqueloba* zeigen besonders nach dem letzten und vorletzten Glazial eine gute Übereinstimmung mit der klimatischen Entwicklung, wie sie durch die O-Isotopen beschrieben wird. Ihr maximales Auftreten korrespondiert exakt mit den interglazialen Klimaoptima. Während dieser Phasen zeigt sie eine weite Verbreitung und ihr bevorzugtes Wassermassen-Habitat liegt im Bereich der gut durchmischten Arktischen Front. In kälteren Interglazialabschnitten ist sie dagegen überhaupt nicht oder nur geringfügig vertreten. Neben *G. quinqueloba* sind auch andere häufigere Subpolararten wie *Globigerina bulloides*, *Globigerinita glutinata* und *Globigerinita uvula* prinzipiell auf interglaziale Maxima beschränkt. Die Verbreitung von *G. bulloides* bezieht sich jedoch nur auf den 'wärmeren' Einflußbereich des Norwegenstroms (Atlantische Domäne), wogegen *G. glutinata* und *G. uvula* im gesamten Untersuchungsgebiet auftreten. Weitere Subpolararten sind nur in geringen Anteilen an der Faunenzusammensetzung beteiligt und wurden, da sie hauptsächlich im südlicheren Teil des Europäischen Nordmeeres vorkommen, durch nordatlantisches Wasser eingedrftet.

Eine lateral ausgedehnte Verbreitung der atlantischen Art *Beella megastoma* konnte für die Abschmelzphasen der Termination II, III und für das Stadium 15 belegt werden, wobei als Ursache ein 'pulsartiges' Einströmen von atlantischem Zwischenwasser angenommen werden kann. Dieser Prozeß, der zumindest in Termination II zeittransgressiven Charakter aufweist, war ein kurzzeitiges ozeanologisches Phänomen, das durch die Etablierung des jeweils nachfolgenden interglazialen Zirkulationssystems beendet wurde.

Detaillierte biometrische Analysen von *G. quinqueloba*, die über den letzten glazial/interglazialen Wechsel bis in die jüngsten Sedimente durchgeführt wurden, beweisen eine systematische 'Klimaabhängigkeit', die sich in kleineren Gehäusen während kälterer Phasen und größeren Gehäusen im Klimaoptimum ausdrückt. Qualitative Abschätzungen an Teilfraktionen zeigen, daß dieses auch auf ältere Stadien übertragbar ist. Besonders in den Stadien 7, 9, 11 und 13 herrschte demnach nicht die interglaziale Stabilität des Strömungssystems vor, wie sie für das Stadium 5.51 und das Holozän erkennbar ist.

MICROPALAEONTOLOGY NOTEBOOK

J. Micropalaeontol. 11 (1): 58, June 1992

First record of the genus *Beela* Banner & Blow, 1960, in upper Pleistocene sediments (past 600Ka) from the Norwegian-Greenland Sea

HENNING A. BAUCH

GEOMAR Research Centre for Marine Geosciences

Wischhofstrasse 1-3

2300 Kiel,

Germany

Planktonic foraminifers from Pleistocene sediments from the Norwegian-Greenland Sea (NGS) have been subject to intense investigation during the past 20 years. This is mainly due to their almost continuous presence in glacial and interglacial times, and hence, their utility for establishing sound O^{18} -isotopic curves. Traditionally, all are assigned to a polar and subpolar group. *Neogloboquadrina pachyderma* (sinistral) is the only polar species, whereas the subpolar group is made up of *Globigerina quinqueloba*, *G. bulloides*, *G. universa*, *N. pachyderma* (dextral), *N. dutertrei*, *Globigerinita glutinata*, *Gl. uvula*, *Globorotalia inflata*, *Gl. truncalutinoides*, *Gl. scitula*. *N. pachyderma* (sinistral) is almost continuously present during glacial/interglacial times. This is in contrast to the subpolar species that show main abundances in interglacial maxima only. Prior to this study, a species belonging to the genus *Beela* has never been mentioned to occur in Pleistocene sediments north of 55° latitude (Holmes, 1984). My specimens exhibit a thin-walled spinose test; trochospiral becoming streptospiral;

last chamber radially elongated but never pointed or digitate; aperture very variable from small umbilical to larger extraumbilical-umbilical. Its size ranges from 200-660µm, but is mainly confined to the 250-500µm mesh-size fraction.

These general characteristics agree well with the emendation of the genus *Beela* by Holmes (1984). Accordingly, the described species will in future be assigned to *Beela megastoma* (Earland).

There is good evidence that *Beela megastoma* is not simply a 'warmer water form' being swept into the NGS by North Atlantic Waters as some of those mentioned above, but a species that seems to be tied to certain recurring deglacial parameters. All this needs further investigation and more detailed results will be published elsewhere.

REFERENCES

- Holmes, N.A. 1984. An emendation of the genera *Beela* Banner & Blow, 1960, and *Turborotalita* Blow & Banner, 1962, with notes on *Orcadia* Boltovskoy & Watanabe, 1982. J. Foram. Res. 14 (2), 101-110.

SIGNIFICANCE OF FORAMINIFERAL TEST SIZE VARIABILITY FOR NORWEGIAN-GREENLAND SEA PALEOCEANOGRAPHIC INTERPRETATIONS

Henning A. Bauch, GEOMAR, Research Center for Marine Geosciences,
Wischhofstraße 1-3, 2300 Kiel, Germany (submitted to Marine Geology)

ABSTRACT

For the first time biometric analyses on shells of *Globigerina quinqueloba* (Natland) are used for paleoceanographic interpretations in the Norwegian-Greenland Sea (NGS). Several box cores have been investigated along a transect (Vøring Plateau-Kolbeinsey Ridge) with sediments covering the climatic changes since the Last Glacial Maximum (LGM).

G. quinqueloba proved to be extremely valuable because it is the most abundant of all subpolar planktic foraminifers in interglacial NGS and also almost ubiquitous during Holocene times. Hence, it is bound to reflect the oceanographic changes that occurred since first interglacial warming.

Methods were carried out by measuring the largest diameter of the test across the umbilical side from appropriate samples of the 63-500 μ m size-fraction. Both, median and mean size variations exhibit a steady increase after LGM. After Termination I sizes eventually reach a constant level with only minor fluctuations. In contrast, peak abundances of specimens occur somewhat later during the climatic optimum (~6000yrs.) and rapidly decrease again in youngest sediments. Essentially, test sizes are much larger at the Vøring Plateau in vicinity of incoming Atlantic Water than further to the west. Moreover, there are strong indications that *G. quinqueloba* first appeared in the south-western part of the NGS with a preliminary major peak in abundance and size well below the Younger Dryas. In fact this species seems to have been present in sizes <125 μ m in this area during almost entire oxygen isotopic Stage 2. This cannot be observed in the more easterly located cores.

It seems likely that size variations as 'tool' for paleoceanographic interpretations are not only valuable for the time since LGM, but can also be applied to older isotopic Stages where abundances of *G. quinqueloba* are low or even non-existing in >125 μ m size-fractions but appear to be high in the 63-125 μ m fraction (e.g., Stage 7, 9, and 11).

STRATIGRAPHIC OCCURRENCE OF *BEELLA MEGASTOMA* (EARLAND) IN PLEISTOCENE SEDIMENTS FROM THE NORWEGIAN-GREENLAND SEA

Henning A. Bauch, *GEOMAR*, Research Center for Marine Geosciences,
Wischhofstrasse 1-3, D-2300 Kiel, Germany (submitted to *Journal Foraminiferal
Research*)

ABSTRACT

Prior to this work, a planktic foraminifer belonging to the genus *Beella* Banner and Blow (1960) has never been mentioned in detail to occur in Pleistocene sediments from the Norwegian-Greenland Sea (NGS). Test sizes range from 200-700µm, but specimens are mainly confined to the 250-500µm mesh-size fraction. The general characteristics of this species agree well with the most recent emendation of the genus *Beella*. Accordingly, the described species is considered to be *Beella megastoma* (Earland). Interpretations of stable isotopes and other micropaleontological data indicate that this type is not simply a 'warm-water form' being swept into the NGS by North Atlantic water e.g., as some other rare foraminifera found in the more south-easterly part of the NGS during oxygen isotopic Stage 5.5, but a species of paleoceanographic significance since it is strongly tied to major meltwater events. Its stratigraphic distribution is confined to Termination II, Termination III, and Termination VI (oxygen isotopic stage boundary 5/6, 7/8, and 15/16) where it always preceeds the interglacial. maximum. Hence, these '*Beella*-Events' represent a particular oceanographic phenomenon and are attributed B₁, B₂, and B₃ respectively.

Die paläo-ozeanographische Entwicklung der Islandsee in den letzten 550 000 Jahren

Lovísa Birgisdóttir

ZUSAMMENFASSUNG

Auf einer Kerntraverse entlang 70°N von der Ostseite des Jan-Mayen-Rückens bis zur Westseite des Kolbeinsey-Rückens wurden Untersuchungen über die paläoozeanographische Veränderlichkeit der Islandsee in den letzten etwa 550000 J.v.H. durchgeführt. Es lassen sich 5-7 relativ gut korrelierbare Abfolgen von tonigen quarzreichen Sedimenten gegenüber foraminiferenreichen Schichten unterscheiden.

Eine stratigraphische Einstufung wurde mit Hilfe der Sauerstoffisotopenbestimmungen an zwei Kernen ermöglicht. Für die Festlegung der Isotopenstadiengrenze 4/5 ist das Auftreten der benthischen Foraminifera *Pullenia bulloides* benutzt worden. Die Aktivität der nahegelegenen Vulkangebiete (Jan-Mayen, Island, Eggvingrunn) zeichnet sich in gut korrelierbaren Tephralagen ab z.B. in den O-Isotopenstadien 1 ca. 11.000a, 2 ca. 14.000a, 5 ca. 127.000a, 7 ca. 211.000a und ca. 228.000a, 8 ca. 272.000a, 11 ca. 400.000a.

Die zeitliche Veränderlichkeit spiegelt sich in dem Kalziumkarbonatgehalt wider, der eine komplizierte Wechselwirkung zwischen verschiedenen Wassermassen dokumentiert und Rückschlüsse auf eine erhöhte Produktivität und Erhaltung des Materials erlaubt. Der Kalziumkarbonatgehalt nimmt generell nach Westen hin ab. Anscheinend kommt die volle Beeinflussung der kalten Wassermassen des Ostgrönlandstromes erst im Gebiet westlich des Kolbeinsey-Rückens zur Geltung. Dort sind die Gew.-% des Quarzes generell höher. Quarzfreie Zonen gibt es nur im Stadium 11 im Kern 23243 und in Stadium 5e in den 4 östlichen Kernen.

Das vollkommene Fehlen von Karbonat vor 330000 J.v.h. fällt mit den tonigen grau-/grün-/roten Litho-Faziesabfolge zusammen. Dies könnte bedeuten, daß während der älteren Kaltzeiten (bis vor ca. 330000 J.v.h.) das Tiefenwasser besonders korrosiv war und das vorhandene kalkige Skelettmaterial aufgelöst wurde. Möglicherweise war die Islandsee während dieser Zeitabschnitte vollkommen eisbedeckt, wodurch jegliche Kalkschalerproduktion "unterbunden" wurde. Für die darauf folgenden jüngeren Kaltzeiten (ab 300000 J.v.h.) ist anzunehmen, daß die Islandsee wenigstens saisonal offen war und eine geringe Produktion ermöglichte.

Ein maximaler Einfluß von "warmen" nordatlantischen Wassermassen ist im Stadium 11 (etwa 423000-362000 J.v.h.) durch sehr hohe Kalziumkarbonat- und Foraminiferengehalte sowie das Fehlen von eisverfrachtetem Material (Quarz, Gesteinsbruchstücke, Feldspat, Schwerminerale und Glimmer) in den 3 östlichen Kernen dokumentiert. Ein ähnliches Bild zeigt sich im Isotopenstadium 5e, etwas weniger ausgeprägt im Holozän.

Unterschiedliche Sedimentationsraten spiegeln wahrscheinlich eine komplexe Wechselwirkung zwischen der Bathymetrie (Bodenströmungen, selektive Lösung) und wandernden Frontensystemen hochvariabler Wassermassen dieses Gebietes (nährstoffreicheres wärmeres Wasser, mehr Produktion) wider.

Dropstones in Europäischen Nordmeer -

Indikatoren für Meeresströmungen

in den letzten 300 000 Jahren

Jens Bischof

ZUSAMMENFASSUNG

Glazimarine Tiefseesedimente im Europäischen Nordmeer (Norwegisch-Grönländische See) enthalten unterschiedliche Proportionen von Dropstones (eistransportierte Gesteinsfragmente), die ein Abbild der Eisdrift darstellen. Die qualitative Dropstone Zusammensetzung gibt Aufschluß über ihre Herkunftsgebiete und ermöglicht in Verbindung mit dem Fundort eine Rekonstruktion der Transportrichtungen. Im Rahmen dieser Studie wurden Dropstones der 0.5 - 2 mm Fraktion aus Großkastengreifern (GKG), Kasten-, Kolben- und Schwerelotkernen von 51 Stationen in der Norwegisch Grönländischen See qualitativ und quantitativ bearbeitet. Aus jedem GKG wurden bis zu 13 Proben gewonnen. Das Material wurde petrographisch klassifiziert und der quantitative Anteil definierter Lithologie-Gruppen für jede Probe bestimmt. Daraus ergaben sich charakteristische regionale und zeitabhängige Verteilungsmuster, die als Ausdruck veränderlicher Eisdiffrichtungen interpretiert werden konnten.

Dropstones aus der Norwegischen See sind grundsätzlich anders zusammengesetzt als Dropstones aus der Grönland- und Islandsee, was für eine ausgesprochen dauerhafte Trennung der Eisdiffrichtung zwischen diesen Meeresräumen spricht. In der westlichen Grönlandsee bestehen Dropstones aus Gesteinen von Ost- und Nordostgrönland, während in der östlichen Grönlandsee Gesteine arktischen Ursprungs dominieren. Die Eisdrift war damit dem Verlauf des rezenten Ostgrönlandstromes sehr ähnlich.

In der Norwegischen See bestehen Dropstones vorwiegend aus Quarz, Feldspat, Granit und Gneis bei nur geringen Anteilen von Sedimentgesteinen, unter denen Silt- und Sandsteine überwiegen, während Karbonate seltener sind. Es wurden Gesteine gefunden, die eine einwandfreie Zuordnung zu definierten Herkunftsgebieten ermöglichen. Aus dem südöstlichen Randbereich stammen Kreide, Feuersteine und Rhombenporphyre, die in der Norwegischen See bis ca. 72°N und 3°W verbreitet sind. Aus Spitsbergen stammen Spikulite und charakteristische Biotit-Gneise, die bevorzugt in der westlichen Norwegischen See gefunden wurden.

Die Dropstones stammen fast ausschließlich aus östlichen Randgebieten der Norwegischen See. Der Einzugsbereich erstreckt sich von Nordwest-Spitsbergen über die gesamte Norwegische Westküste bis nach Nordwest-Schottland und zu den Fäeroer Inseln. Zusammen mit anderen Merkmalen der Dropstone Zusammensetzung ergibt sich das Bild einer zyklonischen (gegen den Uhrzeigersinn drehenden) Drift in der Norwegischen See. Gesteine aus dem südsandinavisch-baltischen Raum wurden bevorzugt in die zentrale Norwegische See transportiert, während das nördliche Vöring-Plateau und die westliche Norwegische See ihr Material vorwiegend aus Nordnorwegen und Svalbard erhielten.

Zwischen 16 und 14 ka veränderte sich dieses Bild grundlegend. Die vormalig dominierenden Kristallingesteine werden durch hohe Anteile klastischer Sedimentgesteine ersetzt, die von Svalbard und dem Barents Schelf stammen und von Eisbergen des abschmelzenden Barents See Eisschildes in süd- und südwestliche Richtung transportiert wurden. Diese Strömung ist bis zum südwestlichen Vöring-Plateau nachweisbar.

Nach 14 ka wird die südwärts gerichtete Strömung zunehmend von 2 nach Norden vordringenden Wassermassen eingeschlossen. Der östliche Arm dieses Systems entwickelte sich zu einem Vorläufer des Norwegischen Küstenstromes und erreichte um ca. 9.7 ka Nordnorwegen. Durch die zentrale Norwegische See drang eine Art 'Proto Norwegenstrom' nach Norden vor. Zwischen beiden Strömungen blieb der südwärts gerichtete Ausstrom aus der Barents See bis ca. 9 ka erhalten und wurde danach von den nordwärts gerichteten Strömungen in den Bereich der Barents See zurückgedrängt. Seine verkümmerten Reste existieren dort als Ost-Spitsbergen- und Bäreninsel Strom. Im Holozän ist der einst bedeutende Ausstrom aus der Barents See zeitweise wieder reaktiviert worden.

MIOCENE TO QUATERNARY PALEOCEANOGRAPHY IN THE NORTHERN NORTH ATLANTIC: VARIABILITY IN CARBONATE AND BIOGENIC OPAL ACCUMULATION

G. BOHRMANN¹, R. HENRICH² and J. THIEDE²

¹*Alfred-Wegener-Institut für Polar- und Meeresforschung
Columbusstraße
D-2850 Bremerhaven, F. R. Germany*

²*GEOMAR, Forschungszentrum für Marine Geowissenschaften
Wischhofstraße 1-3
D-2300 Kiel 14, F. R. Germany*

ABSTRACT. Based on accumulation rates of the bulk sediment and some pelagic components (carbonate, total organic carbon, and biogenic opal fractions) major changes in the paleoceanography of the northern North Atlantic from Miocene to Recent are discussed. Interactions of various processes could have created a stepwise evolution of cold climates in the northern hemisphere. Prominent events were the onset of deep water export across the Greenland-Scotland Ridge with the first significant overflow across the Iceland-Scotland segment occurring most probably between 13 - 11 Ma and at about 7 Ma across the Denmark Strait. Oscillations of sea-level around the critical sill depth in the early phases of the subsidence may have influenced the oceanic circulation in the North Atlantic as well as in the Norwegian-Greenland Sea. Furthermore the potential of the Norwegian-Greenland Sea to form and export dense deep water, increased the meridionality in the northern hemisphere. During 10.2 - 9.3, 8.7 - 8.2, 5.8 - 5.4 and 4.8 - 3.2 Ma representing times of increased water mass exchange to the central North Atlantic, carbonate deposition occurred. On the other hand, higher opal accumulation rates and decreased water mass exchange (9.3 - 8.7 and 5.4 - 4.8 Ma) may be correlated with sea-level oscillations around the critical sill depth of the Greenland-Scotland Ridge. The build-up of northern hemisphere cooling can probably traced back to late Miocene times with modest ice-rafted debris input. A significant stepwise increase of northern hemisphere cooling occurred around 4 Ma and finally resulted in the first large extension of sea ice and ice-rafting in the entire North Atlantic at ca. 2.6 Ma.

*U. Bleil and J. Thiede (eds.), Geological History of the Polar Oceans: Arctic Versus Antarctic, 647-675.
© 1990 Kluwer Academic Publishers. Printed in the Netherlands.*

CYCLES, RHYTHMS, AND EVENTS IN QUATERNARY ARCTIC AND ANTARCTIC GLACIOMARINE DEPOSITS

R. HENRICH
*GEOMAR Forschungszentrum für Marine Geowissenschaften
Wischhofstraße 1-3
D-2300 Kiel 14, F.R. Germany*

ABSTRACT. Highly variable facies patterns of sub-Arctic glaciomarine continental margin environments contrast with less pronounced variations in Antarctic deposits. Shallow portions of the sub-Arctic shelves reveal regressive facies successions comprising basal lodgement till and high energy reworked top sequences during glacio-isostatic uplift. Deeper portions of sub-Arctic shelves record advance/retreat cycles of continental ice with up to 150 m thick glacial units which are separated by glacial erosional surfaces. Greatest thicknesses occur on the shelf break and upper slope with depocenters situated at the mouth fans. Prograding slope sequences reveal a complex sigmoid-oblique seismic character formed by alternating build-up during glacial progradation and depositional bypass/erosion in the topset during interglacial periods. Antarctic shelf deposits reveal biogenic siliceous muds or gravelly diamictites with admixtures of a monogenetic biogenic epifauna deposited at low sedimentation rates.

Sub-Arctic and Antarctic deep-sea sediment records reflect glacial/interglacial variations in carbonate and opal productivity and ice-rafted debris input. In Norwegian - Greenland Sea's deep sea pelagic environments widespread distribution of dark diamictites indicates extensive advances of the continental ice-sheets onto the shelves and permits connection of open ocean with shelf records. In the Weddell Sea, glacial, transitional and interglacial facies patterns correspond to advance/retreat cycles of the Antarctic ice-sheet, episodic development of floating ice-shelves, variations in the extension of sea ice coverage and cyclic development of polynyas within the Weddell Sea sea ice-cover.

*U. Bleil and J. Thiede (eds.), Geological History of the Polar Oceans: Arctic Versus Antarctic, 213-244.
© 1990 Kluwer Academic Publishers. Printed in the Netherlands.*

Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian–Greenland Sea

R. Botz^a, H. Erlenkeuser^b, J. Koch^c and H. Wehner^c

^aGeologisch–Paläontologisches Institut, Universität Kiel, Olshausenstrasse 40–60, 2300 Kiel, Germany

^bInstitut für Kernphysik, C14-Lab, Universität Kiel, Olshausenstrasse 40–60, 2300 Kiel, Germany

^cBundesanstalt für Geowissenschaften und Rohstoffe, 3000 Hannover 51, Germany

(Received July 3, 1990; revision accepted October 30, 1990)

ABSTRACT

Botz, R., Erlenkeuser, H., Koch, J. and Wehner, H., 1991. Analysis of sedimentary organic matter of a glacial/interglacial change (oxygen isotope stage 6/5) in the Norwegian–Greenland Sea. *Mar. Geol.*, 98: 113–119.

Organic petrographical investigations of Norwegian Sea sediments deposited during oxygen isotope stages 6 and 5 show significant changes in the relative amounts of “reactive” (vitrinite and liptinite) and “inert” (inertinite and graphite) particles. The $\delta^{13}\text{C}$ values of the total organic fraction possibly reflect the variable content of reactives, i.e. the isotopic composition is more negative (to -23.9‰) when the reactive components increase. The *n*-alkane distribution shows that the soluble organic matter deposited during late stage 6 and 5e reveals relatively low odd–even-predominance indices (OEP) associated with shorter chain lengths. This indicates a relatively higher marine algal contribution during stage 6 and 5e compared with stage 5d to 5a.

A climatic record for the last 12,000 years from a sediment core on the Mid-Norwegian Continental Shelf

KÅRE ROKOENG, HELMUT ERLLENKEUSER, MAGNE LØFALDLI & ODDVAR SKARBØ

Rokoengen, K., Erlenkeuser, H., Løfaldli, M. & Skarbø, O.: A climatic record for the last 12,000 years from a sediment core on the Mid-Norwegian Continental Shelf. *Norsk Geologisk Tidsskrift*, Vol. 71, pp. 75–90. Oslo 1991. ISSN 0029–196X.

The local depositional environment in Late Weichselian and Holocene time is inferred from investigations including sedimentology, geotechnical properties, biostratigraphy, stable isotopes and radiocarbon dates from a 265 cm long vibrocorer sample from 165 m water depth at 64°59'N and 9°14'E. The lower part of the core is interpreted to be extensively remoulded by iceberg scouring, while the top 160 cm gives a continuous record for the last 12,000 years. Three radiocarbon dates and a volcanic ash zone (Vedde Ash Bed) provide ages ca. every 600 years for the period 12,000 to 10,000 years BP. Minimum content of boreal foraminifera (representing the most arctic conditions) occurred from before 12,000 to about 11,300 and from 11,000 to 10,400 years BP. The transition from arctic to boreal conditions is very marked at about 10,300 \pm 200 years BP. Later minima of boreal foraminifera (colder events) are recorded around 10,000 to 9000 years BP, with variations shorter than the time resolution. The core provides a detailed record during the deglaciation period of Scandinavia after 12,000 years BP, and shows good correlation to land data. The upper part of the core, representing the last 9000 years, shows maximum content of the boreal *Trifarina angulosa* (optimal climatic conditions) around 5000 years BP and then decreasing values up to present time.

Kåre Rokoengen, IKU (Continental Shelf and Petroleum Technology Research Institute), N-7034 Trondheim, Norway; Helmut Erlenkeuser, Institute of Nuclear Physics, ¹⁴C-Laboratory, University of Kiel, Olshausenstr. 40–60, D-2300 Kiel, Germany; Magne Løfaldli, IKU, Present address: Strømlab, Havneveien 4, N-2013 Skjetten, Norway; Oddvar Skarbø, IKU, Present address: MRB (Møre og Romsdal Bedriftsrådgivning), Blindheimsenteret, N-6012 Ålesund, Norway.

OXYGEN ISOTOPE STAGE 5 IN THE NORWEGIAN-GREENLAND-SEA: OCEANOGRAPHIC AND ECOLOGICAL ASPECTS FROM ISOTOPIC AND BENTHIC FORAMINIFERAL EVIDENCE

H. Erlenkeuser and F. Haake (Special Research Project 313, Univ. of Kiel, Kiel, Germany)

Oxygen isotope stage 5 (OIS 5), with particular emphasis on substage 5a, was studied with high (up to 1 cm) resolution through isotopes of planktic and benthic foraminifera, both epi- and endobenthic taxa, benthic foraminiferal abundancies, shell weights, and total organic carbon isotopes in cores from the Norwegian/Greenland Sea (NGS).

The isotopic records reveal a fine structure which is well consistent among the different cores and partly reflects global climatic events superimposed on the well-known broader isotopic pattern. Isotope differences between *C. wuellerstorfi* and *O. umbonatus* suggest that the $\delta^{18}\text{O}$ signal of *C. wuellerstorfi* from NGS sediment samples could be biased toward deep-convected light $\delta^{18}\text{O}$ of brackwater brines, the effect depending on core location, water depth and paleoceanographic context.

The benthic foraminifer *P. bulloides* indicates phases of North Atlantic water being advected to the NGS at the surface and readily mixed to the bottom. In this sense formation of deep-waters was most direct and thorough in the NGS including the Fram Strait in late OIS 5a. Interestingly and in contrast to OIS 5a, there is no evidence in our cores that during OIS 5c North Atlantic waters reached the NGS as surface waters, except perhaps in the Iceland Sea.

As to OIS 5e, ecological conditions appear to improve according to our eastern cores only under the cooling climate in the trailing phase of this warm stage. If deep water formation was generally reduced in the NGS under peak interglacial conditions, greenhouse warming might become accentuated in the future as the uptake of anthropogenic CO_2 by the NGS waters would be substantially reduced.

Isotopic and ecological evidence on deep convection in the Norwegian Sea from a highly resolved sediment record of oxygen isotope stage 5.

H. Erlenkeuser and F. Haake

(Special Research Programme 313 "Environmental Changes: The Northern North Atlantic", Kiel Univ., Germany)

A high-sedimentation core from a climate-sensitive position (core 23071, 71°N, 3°E, 1308 m, east Norwegian Sea off mid Norway) provided well resolved details of the oceanographic response under climatic conditions intermediate between the limiting states of the extreme glacial and the peak interglacial.

Oxygen isotope stage 5 was studied with high (up to 1 cm) resolution through isotopes of planktic and benthic foraminifera, both epi- and endobenthic taxa, benthic foraminiferal abundancies, single-shell weights, and total organic carbon isotopes.

The isotopic record reveals a fine structure which partly reflects global climatic events superimposed on the well-known broader isotopic pattern. Abundance of the epibenthic species *C. wuellerstorfi* reveals pronounced peaks in the interstadials 5c and 5a, in the transitions 5a/4 and 5e/5d, but is low in the interglacial stage itself. This pattern is corroborated by the single-shell weights of both the epibenthic species and the planktic foraminifer (*N. pachyderma*, left coiling). The benthic-planktic carbon isotope difference suggests an intensified exchange between the bottom water story and the surface layer in the interstadials, particularly in stage 5a and the transition 5a/4. An extended meltwater signal, possibly double-peaked and followed by a Younger-Dryas-like cooling phase, and poor of foraminiferal shells, precedes stage 5e.

These findings indicate that ecological conditions for the growth of both epibenthic and planktic species improve when a less stable stratification of the water column develops and favours the water turnover - and recycling of nutrients - under colder climatic conditions as compared to the times of deglaciation or interglacial warmth.

As a conclusion, a CO₂-induced greenhouse effect might become accentuated in the future if the stability of the water column in the Nordic Seas increased in general as the sea surface temperatures rise.

Pullenia bulloides (Orbigny) in Sediments of the Norwegian/Greenland Sea and the Northeastern Atlantic Ocean: Paleo-Oceanographic Evidence

F.-W. Haake

Geologisch-Paläontologisches Institut der Universität, 2300 Kiel, Germany

H. Erlenkeuser

Institut für Kernphysik der Universität, C-14-Labor, 2300 Kiel, Germany

U. Pflaumann

Geologisch-Paläontologisches Institut der Universität, 2300 Kiel, Germany

ABSTRACT: The distribution of *Pullenia bulloides* (ORBIGNY) in sediments of the Holocene (isotope stage 1), the late isotope stage 5, and the isotope substage 5e from the Norwegian/Greenland Sea is discussed. The different depth ranges during these isotopic stages are obviously governed by the intensity of the deep water formation.

INTRODUCTION

The benthic foraminifer *Pullenia bulloides* (Orbigny) is a nearly cosmopolitan species (Brady, 1884). In the North Atlantic Ocean it reveals a widespread occurrence in the surface sediments as well as in the deeper core sections (Phleger et al., 1953). By contrast, the Norwegian sedimentary records have only encountered this species during interglacial periods, including the Holocene; the glacial sequences are entirely barren of *Pullenia bulloides* (Streeter et al., 1982; Haake and Pflaumann, 1989).

PALEO-OCEANOGRAPHIC EVIDENCE

Holocene

During Termination Ib (10,000–8,000 yrs. B.P.) a pioneer population of *Pullenia bulloides* began to settle in the Norwegian/Greenland Sea (Figure 1) along with other species like *Epistominella exigua*, *Cibicides lobatulus*, and *Gyroidina lamarckiana* (Sejrup et al., 1984). By contrast, the *Cibicides wuellerstorfi* population was already established during Termination Ia at some places. Sediment surface samples of several large box cores from the Norwegian/Greenland Sea

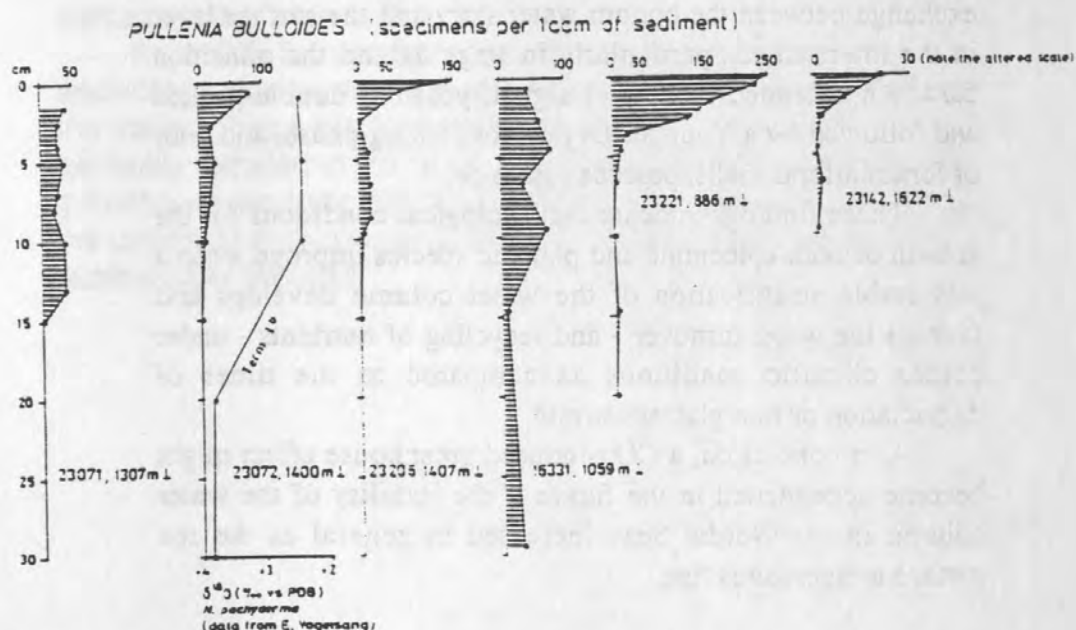


FIGURE 1. Abundance of *Pullenia bulloides* in Holocene sediments of the Norwegian Sea.

Letter Section

The Vesterisbanken Seamount (Greenland Basin): Patterns of morphology and sediment distribution

P. Hempel^a, R. Schreiber^b, L. Johnson^c and J. Thiede^a

^aGEOMAR, Forschungszentrum für Marine Geowissenschaften, Wischhofstrasse 1–3, D-2300 Kiel 14, FRG

^bKrupp Atlas Elektronik GmbH, Seebaldsbrücker Heerstrasse 235, D-2800 Bremen 44, FRG

^cDepartment of the Navy, Office of Naval Research, Arlington, VA 22217-5000, USA

(Received March 6, 1990; revision accepted October 23, 1990)

ABSTRACT

Hempel, P., Schreiber, R., Johnson, L. and Thiede, J., 1991. The Vesterisbanken Seamount (Greenland Basin): Patterns of morphology and sediment distribution. *Mar. Geol.*, 96: 175–185.

A closely spaced grid of seismic reflection profiles has permitted a description of the structure of the Vesterisbanken Seamount (Greenland Sea) and the distribution of the surrounding sediments. This isolated seamount is situated at 73°30'N, 9°10'W in the Greenland Basin and rises from the basin floor at a water depth of about 3100 m to ~130 m below sea level; the maximum inclination of its slope is 26°. It is of basaltic origin, and reveals chaotic reflectors on the seismic profiles. No inhomogeneities are visible within the volcanic rocks of Vesterisbanken and the basement complex surrounding it. Dredge samples from the summit of Vesterisbanken reveal an age of ~100,000 years. In the seismic records, there was no sediment cover discernable on top of or on the flanks of the seamount. At the base of Vesterisbanken, the seismic reflection characteristics suggest an alternation of sediments and basaltic rocks, the latter probably being the result of young lava flows. In some places the volcanic rocks disturb the sedimentary sequence to such a high degree, that the stratification is virtually eliminated. Volcanic activity also occurs in the vicinity of the seamount: for example, about 20 km northwest of Vesterisbanken an intrusion has pierced through 1000 m of sediment, almost reaching the seafloor. The sediment thickness is variable and it smooths the irregular basement topography. In addition, the sediment is characterized by local unconformities associated with onlap structures.

Tectonophysics, 190 (1991) 95–108
Elsevier Science Publishers B.V., Amsterdam

Spinifex basalts with komatiite–tholeiite trend from the Nansen-Gakkel Ridge (Arctic Ocean)

R.K. Mühle^a, H. Bohrmann^a, P.K. Hörmann^b, J. Thiede^c and P. Stoffers^a

^aGeologisch-Paläontologisches Institut und Museum der Universität, 2300 Kiel, FRG

^bMineralogisches Institut der Universität, 2300 Kiel, FRG

^cGeomar, Forschungszentrum für Marine Geowissenschaften der Universität, 2300 Kiel, FRG

(Received September 27, 1989; revised version accepted February 26, 1990)

ABSTRACT

Mühle, R.K., Bohrmann, H., Hörmann, P.K., Thiede, J. and Stoffers, P., 1991. Spinifex basalts with komatiite–tholeiite trend from the Nansen-Gakkel Ridge (Arctic Ocean). In: J. Francheteau, O. Eldholm and P. Miles (Editors), *The Geology, Geophysics and Metallogeny of the Present-Day Oceans*. *Tectonophysics*, 190: 95–108.

During cruise ARK IV/3 with RV *Polarstern* (1987) volcanic rocks were recovered from the Nansen-Gakkel Ridge (NGR), a slow spreading (half rate approximately 0.5 cm) ridge with an axial depth of more than 5000 m. The NGR is one of the slowest and deepest mid-ocean ridges so far known and calculations based on the distance of sampling location from the axial valley yielded ages of approximately 600 ka for the rocks investigated here.

According to petrographic and geochemical results, i.e. spinifex textures, $mg > 70$ and $MgO > 9$ wt.%, the volcanics are termed komatiitic basalts. Dark spherical droplets of basaltic composition within the komatiitic basalts are believed to be relicts of an incomplete magma-mixing whose basaltic end-member could well account for the enriched character of the NGR basalts in terms of rare earth elements, Ti and incompatible trace elements.

Based on Nd-isotope as well as high Sm/Nd ratios, mantle metasomatism (i.e. veined-mantle model) could be responsible for the enrichment of incompatible trace elements in the source region of komatiitic basalts of the NGR.

6.8 Cycles, Rhythms, and Events on High Input and Low Input Glaciated Continental Margins

R. Henrich

1 Introduction

Today, oceans and shelves in the northern and southern hemispheres are strongly influenced by glacial processes. Together with mountain glaciations, about 10% of the Earth's surface is covered by ice and snow. During the Cenozoic, as well as in earlier glacial periods, variations in the magnitude and dimension of the Earth's ice and snow cover resulted in repetitive shifts of the global climate through changes in albedo and total ice volume. Development of the Antarctic ice cap in the early Cenozoic (Kennett 1977) and the onset of Northern Hemisphere glaciation in the late Cenozoic (Plafker and Addicot 1976; Armentrout 1983; Henrich et al. 1989 and references therein) mark a progressive global cooling that is well documented in the climatic records of the oceans (Miller et al. 1987). Superimposed on these long-term changes in Earth's climate – which correspond to specific plate tectonic and paleoceanographic settings – are short-term changes that are controlled primarily by cyclic variations in Earth's orbital parameters, e.g., Milankovitch cycles.

In addition to the Cenozoic, extensive glaciations are documented during other periods of Earth's history, such as the Proterozoic and the Permocarboneous Gondwana glaciations (Frakes and Crowell 1975). During the Pleistocene, more than 40% of the Earth's continental shelves were glaciated (Climap 1976, 1981). Glaciations also influence continental margins through sea level fluctuations, with the consequent migration of facies belts, changes in width of the continental shelves (Beard et al. 1982), and variations in the quantity and type of continental erosional products and sediment delivery to slope and deep sea environments (Ruddiman 1977; Thiede et al. 1986; Henrich et al. 1989). Glaciations indirectly influence nonglaciated continental margins by perturbing high level atmospheric circulation, with its associated variations in aeolian dust supply and oceanic productivity (Sarnthein et al. 1982; Stein 1986a).

Ancient glaciomarine sections have been studied extensively by numerous workers (see bibliography in Eyles et al. 1985 and Edwards 1986). Studies of modern glaciomarine environments were comparatively few until about 20 years ago, but much progress has been achieved since then. A summary of our knowledge on glaciomarine environmental settings has been compiled in a special volume on *Glaciomarine Sedimentation*, edited by B. Molnia (1983), and in special issues of *Marine Geology* (Volume 57, 1984; Volume 85, 1989).

Einsle et al. (Eds.)
Cycles and Events in Stratigraphy
©Springer-Verlag Berlin Heidelberg 1991

Sedimentary facies of glacial-interglacial cycles in the Norwegian Sea during the last 350 ka — reply

Rüdiger Henrich and Jörn Thiede

GEOMAR, Forschungszentrum für Marine Geowissenschaften, Geb. 4, Wischhofstrasse 1-3, D-2300 Kiel 14, F.R.G.

(Received April 10, 1990; accepted June 19, 1990)

The comment by Thomson on our paper presents an alternative model for the early diagenesis of the dark diamictos which are intercalated in glacial sediments over wide areas of the Norwegian-Greenland Sea. The principle difference in the approach of Thomson and our model is that Thomson deduces the early reactions to variations in flux rates and quality of organic matter without changes in bottom-water oxygen levels. We will argue instead that early diagenetic processes have been triggered essentially by changing bottom-water properties.

Thomson's diagenetic model for metal relocations in sediment sections with dark diamictos provides a more detailed and elaborate view of the successive diagenetic environments that we only briefly discussed in our paper (Mar. Geol., 86: 312-313, fig.17). In fact downward movement of a secondary oxidation front into the dark diamictos is responsible for the observed metal concentration profiles within and on top of the diamictos. For comparison, see the discussion on oxidation front migration into turbidites by Buckley and Cranston (1988). Also, these diagenetic reactions clearly are not contemporaneous with deposition of the diamictos. They occur with a time lag of less than 1 ky to 3 ky as suggested by oxic sediment-filled burrows truncating the diagenetic iron laminations concentrated at the redox boundary. In conclusion, there is no discrepancy between Thomson's and our views on the succession of diagenetic processes that caused the observed metal relocation profiles, but we do gratefully acknowledge Thomson's more detailed discussion on these aspects.

Two principally different mechanisms triggering the diagenetic reactions have been presented by Thomson and us. Indeed, the major open question is whether the diagenetic observations can only be

explained by changes in flux rates and quality of organic matter (e.g. Thomson's alternative model), or whether these shifts have been essentially triggered and accelerated by changing bottom-water properties (our model). In order to approach this difficult problem, we will first summarize other circumstantial evidence for changing bottom-water conditions during glacials and interglacials in the Norwegian-Greenland Sea, and then attempt to evaluate our model in more detail.

Glacial sediments in the Norwegian-Greenland Sea generally reveal a low diversity of benthic organisms, and *Cibicidoides wuellerstorfi*, a typical epibenthic foraminifer adapted to full oxygenated bottom-water conditions (Zahn et al., 1986; Lutze and Thiel, 1989), does not occur in glacial sediments. Also, there is a strong glacial/interglacial contrast in bioturbation features and intensity with a much richer and denser ichnofacies in the interglacial sediments. Despite the possibility that some of the shallow endobenthic foraminifera might have been adapted to low-oxygen conditions, the sporadic occurrence of sponge spicules in glacial sediments from submarine ridges demonstrate that oxygenated bottom waters were present. This is further supported by SEM dissolution studies indicating overall good carbonate preservation during "normal glacial" conditions. In conclusion, we assume that during long glacial periods bottom waters still were oxygenated, but that the bottom-water exchange and overall oxygen content was lower than during interglacials. This is further demonstrated by regional differences in glacial $\delta^{13}\text{C}$ values in benthic foraminifera in the Norwegian-Greenland Sea and North Atlantic, with more negative values in the Norwegian Sea (Jansen et al., 1989). The rapidly deposited diamictos are bereft of benthic organisms and reveal only very low

Use and Misuse of the Seafloor

Edited by

K.J. HSÜ and J. THIEDE

Report of the Dahlem Workshop on
Use and Misuse of Seafloor

Berlin 1991, March 17–22

Program Advisory Committee:

K.J. Hsü and J. Thiede, Chairpersons
J.R. Cann, P.J. Cook, J. Francheteau,
B.U. Haq, E. Seibold



JOHN WILEY & SONS

Chichester • New York • Brisbane • Toronto • Singapore

1

Introduction

K.J. HSÜ¹ and J. THIEDE²

¹ETH-Zentrum, Geologisches Institut, Sonneggstr. 5, 8092 Zürich, Switzerland

²GEOMAR-Forschungszentrum für marine Geowissenschaften, Wischhofstr. 1-3, Geb. 4,
2300 Kiel 14, F.R. Germany

The seafloor covers a vast expanse of our planet. The resources in its shallow and deep parts have been used and exploited at an ever-increasing pace since humankind has learned to travel across the seas and to use its living and nonliving resources. The marine science community from many countries, therefore, is concerned that the use of global seafloors might soon turn into a misuse, damaging major sectors of the even today, mostly pristine submarine surface of our planet. This misuse would produce a legacy of unknown and potentially very dangerous consequences for future humankind. Scientists, therefore, are obliged to assess not only the properties of the natural marine environments and their resource potential, but also to hinder industry, governments, and researchers from misusing this treasure belonging to the whole of humankind. Mineral riches are an archive of present and past global environments; they also support a great diversity of marine life. Therefore, the results of this Dahlem workshop are directed not only to the scientific community but also to politicians, governments, industry, as well as national and international agencies.

Leaders of the marine geosciences community meet periodically to evaluate what has been recently achieved and to make recommendations concerning the emphasis of our research efforts in the near future. Workshops have been organized by the Commission on Marine Geology (CMG) of the International Union of Geological Sciences (IUGS). The first was held at Honolulu, Hawaii in 1971, the second at Mauritius in 1976, and the third at Heidelberg, Germany in 1982. The assessments which emerged have proven successful, with resulting recommendations being implemented by oceanographical researchers from various institutions, and by the international ocean drilling program, which has been active since 1968.

Eric Simpson, a past chairman of CMG, proposed in 1980 to schedule a conference to assess nonliving resources on seafloor. In addition, the report of the third workshop of CMG (Thiede 1983) pointed out that known resources include manganese nodules, phosphates, polymetamorphic sulfides, and, of course, oil and gas in offshore areas. However, it also spelled out the need for better exploration tactics, better exploitation

LAMINATED GLACIAL SEDIMENT HORIZONS IN THE NORTH ATLANTIC (MAURY CHANNEL, 3300M WATER DEPTH)

S.J.A. Jung (Geologisch- Paläontologisches Institut der Christian - Albrechts - Universität zu Kiel, Kiel, Germany), H. Erlenkeuser, A. Rosell, M. Sarnthein

Sediments in the NE Atlantic are crucial for reconstructing past changes in the surface and deep water circulation between the North Atlantic and the Norwegian-Greenland Sea especially, the variations of the North Atlantic Drift and the Norwegian overflow water, i.e. the source of the North Atlantic Deep Water.

Sediment core 17049 was retrieved from 3331m on the Hatton Sediment drift at the southeastern Maury Channel, which today forms under the control of bottom currents of southern (Antarctic) origin. Oxygen isotope stratigraphy shows that in this core, peak and early glacial stages 8.4, 6.4, 3/2 and the Younger Dryas are marked by up to 30 cm thick laminated yellowish- gray and dark olive grey foram free mud. These are the first laminated sediments ever described from the deep northern Atlantic. Interesting to note that the concentrations of organic carbon in the dark laminae are lower than 0,1 %, suggesting very low ocean productivity at that time. This is also supported by the high epibenthic $\delta^{13}C$ values at the top and the base of each lamina horizon. Based on Uk(37)- values, sea surface temperatures reached an absolute minimum lower than 8-10° C.

By now the laminated intervals are difficult to interpret since they were neither controlled by excessive carbon fluxes nor by unusually low oxygen content of the bottom water. A drastic lack of nutrients and strong remineralisation are discussed as the possible origin.

Quantitative radiolarian slides
prepared from soft marine sediments

Sigurd Locker

Sonderforschungsbereich 313
Christian-Albrechts-Universität
D-2300 Kiel, Germany

ABSTRACT

A technique for preparing quantitative slides from soft marine sediments is described. This technique can be applied to radiolarians and other coarse sediment particles. The preparation procedure comprises four steps: Freeze drying, chemical treatment, wet sieving of the bulk sediment, and sedimentation of the dry coarse fraction. Four formulas which refer to three general cases of calculating radiolarian or other particle frequencies are included.

INTRODUCTION

In the marine geosciences, quantitative slides of coarser sediment particles (between 5 and 300 μm) are used to determine sedimentological and biocoenotical parameters. These data are applied to develop paleoenvironmental and paleoceanographical scenarios. Depending on the size of particles, several techniques are introduced to prepare quantitative slides from various sediment samples. Related to these techniques, different methods have been described to calculate particle frequencies of bulk sediments.

At present, three methods of preparing slides from coarser sediment particles are preferred. All provide statistically sufficient data for quantitative interpretations.

(1) During the 1970's a pure pipetting method which uses volume aliquots of the suspended bulk sediment was applied to diatom studies (Schrader, 1974; Schrader and Gersonde, 1978). But this method has the disadvantage that particles are distributed non-statistically, forcing total cover glasses to be counted. The indicated disadvantage was remedied by the settling dish method (Batterbee, 1973; Abelmann, 1985; improved by Gersonde in Koc Karpuz and Schrader, 1990), which combines pipetting and settling techniques. According to this method the particles are distributed statistically over the cover glasses, thus making it possible to conduct representative counts of selected traverses. Both the described methods are restricted to smaller particles (usually $>5 \mu\text{m}$). Frequency calculations of diatoms or other small particles are referred to defined counting areas and defined volumes of the sample.

(2) The indicator grain method was originally introduced to pollen and spore analysis (Benninghoff, 1962; Stockmarr, 1971; Laws, 1983) but is applied now also to diatom (Kaland and Stabell, 1981) and dinoflagellate studies (Miller, Mudie and Scott, 1982). Defined quantities of marker or indicator grains, which may be spores or microspheres, are added to the unsieved or sieved but suspended sediment sample, and aliquants are prepared.

PLANKTON AND TEPHRA EVENTS ON THE CONTINENTAL MARGIN OFF MID-NORWAY DURING TERMINATION I

Sigurd Locker and Frank Blaume
Sonderforschungsbereich 313, Universität Kiel

Helmut Erlenkeuser
Institut für Reine und Angewandte Kernphysik, Universität Kiel

Jan Rumohr
GEOMAR, Forschungszentrum für Marine Geowissenschaften, Kiel

ABSTRACT

A high accumulation area on the continental slope west of Gamlembanken (67°N-08°E, 1000 m of water depth) provided a composite section comprising >900 cm of postglacial sediments, which were studied for calcareous and siliceous plankton, and tephra particles.

The first appearance of coccolithophorids, diatoms and radiolarians indicates that northern Atlantic surface waters entered the area off mid-Norway near 13,300 ¹⁴C YBP, thus establishing a weak precursor of the Norwegian Atlantic Current along the shelf edge. According to plankton data, this precursor current persisted throughout Boelling/Alleroed times and also the Younger Dryas, when the Vedde ash settled in the area at 10,600 ¹⁴C YBP. Due to an increased nutrient supply to surface waters, diatoms developed a strong acme at 10,250 ¹⁴C YBP. Coccolithophorids and radiolarians attained higher frequencies only subsequent to ice rafting after 9,650 ¹⁴C YBP, which presumably corresponds to the full establishment of the Norwegian Atlantic Current off mid-Norway. The maximum of radiolarians, amounting to 13,400 skeletons/gram sediment, appeared only after Atlantic time at about 3,800 ¹⁴C YBP.

INTRODUCTION

During the last years several depositional sites have been detected along the Norwegian to Spitsbergen continental margin which provided high resolution records of late Pleistocene to Holocene paleoceanographic events. The sediments recovered have been studied on sediment properties, oxygen and carbon isotopes, and various protistan groups (Bjoerklund, Thiede and Høltedahl, 1979; Jansen et al., 1983; Jansen and Bjoerklund, 1985; Rokoengen et al., 1991; Weinelt et al., 1991; Koc Karpuz and Jansen, 1992; Sarnthein et al., 1992), which contributed to decipher important aspects of the deglaciation history of the Norwegian-Greenland Sea.

One of the most comprehensive sediment sequences has been obtained from the high accumulation area of Gamlembanken, located on the continental slope off mid Norway (Figure 1). The area has been mapped in detail by 3.5 kHz subbottom profiling and sediment sampling (Blaume, 1990, 1992; Rumohr, 1990a, subm.). This paper presents the results of sedimentological and paleontological investigations performed on cores GIK 23312-1/2 and GIK 23331-1/2 from the highaccumulation area. Both cores

Haliclona oculata (Porifera) aus den *Littorina*-Schichten von Løkken, Jütland, Dänemark.

Mit 1 Abbildung und 1 Tabelle.

ERLEND MARTINI & SIGURD LOCKER.

Kurzfassung.

Aus den quartären *Littorina*-Schichten von Løkkens Blånaese, Jütland, Dänemark, werden Reste eines Schwammes beschrieben und der Art *Haliclona oculata* (LINNAEUS 1759) zugeordnet.

Abstract.

[MARTINI, ERLEND, & LOCKER, SIGURD: *Haliclona oculata* (Porifera) from the *Littorina* Beds at Løkken, Yilland, Denmark. – *Senckenbergiana lethaea*, 71 (5/6): 377–382, text fig. 1, tab. 1; Frankfurt am Main, 1.6.1992.]

From the Quaternary *Littorina* Beds at Løkkens Blånaese, Yilland, Denmark, remains of a sponge are described and are placed with *Haliclona oculata* (LINNAEUS 1759).

Einleitung.

Isolierte monaxone Schwammnadeln sind aus verschiedenen tertiären Süßwasser-Ablagerungen bekannt geworden und können in bestimmten Lagen angereichert vorkommen. Derartige Funde sind z.B. aus dem Mittel-Eozän von Messel (HEIL 1964; MARTINI & RIETSCHER 1978), aus dem Unter-Oligozän von Sieblos/Rhön (MARTINI & SCHRADER 1988) und aus dem Miozän vom Oberelsbacher Graben/Rhön (MARTINI, unveröffentlicht) dokumentiert. Vollständige Gemmulae von Süßwasserschwämmen konnten im Mittel-Eozän von Messel nachgewiesen werden (MÜLLER & ZAHN & MAIDHOF 1982). Alle diese Funde können wahrscheinlich

Anschriften der Verfasser: Prof. Dr. E. MARTINI, Geologisch-Paläontologisches Institut der Universität, Senckenberg-Anlage 32–34, D-6000 Frankfurt am Main 1. – Dr. S. LOCKER, Geologisch-Paläontologisches Institut der Universität, Olshausenstr. 40–60, D-2300 Kiel.

11. CLUSTERS OF SPONGE SPICULES FROM QUATERNARY SEDIMENTS AT SITES 685 AND 688 OFF PERU¹

Erlend Martini² and Sigurd Locker³

ABSTRACT

Clusters of sponge spicules found in Quaternary deep-water sediments at Sites 685 and 688 off Peru represent single individuals of small sponges or fragments of larger sponges. The spicule assemblages constituting these clusters probably represent a few demosponge species of the subclass Tetractinomorpha and order Astrophorida, because triaenes and microscleric euasters, as well as abundant monaxons, are present. As proved by incorporated Neogene diatoms, these spicule clusters are allochthonous. The sponge individuals probably inhabited deeper neritic environments during late Neogene time.

INTRODUCTION

Sponge spicules were noted as minor constituents of the regular siliceous microfossil assemblages in most of the lower Miocene to Holocene sequences drilled during Ocean Drilling Program Leg 112 off Peru (Fig. 1). These spicules are associated with common diatoms, few silicoflagellates, and scattered radiolarians. From 10 sites drilled (679 through 688), the Quaternary sequences of Sites 685 and 688 were selected to study the occurrence of isolated sponge spicules and of frequently observed clusters of sponge spicules.

Site 685 (9°06.78'S, 80°35.01'W) is situated on the lower slope of the Peru Trench, at a water depth of 5070.8 m. The Quaternary sequence consists of 200 m of diatomaceous mud and contains fossils of Pleistocene age, most of which were transported from the shelf. Site 688 (11°32.26'S, 78°56.57'W) is also located on the lower slope of the Peru Trench, in a water depth of 3819.8 m and about 30 km landward of the trench axis. Its upper 339 m is composed of bioturbated Quaternary diatomaceous muds, from which sponge spicules and clusters were recovered and studied. Evidence of reworking and downslope transport is apparent in several fossil groups, but benthic foraminiferal assemblages are representative of present water depths (Suess, von Huene, et al., 1988).

Isolated sponge spicules have been sporadically described and/or depicted in DSDP/ODP publications (Dumitrică, 1973; Hajós, 1973, 1975; Kennett, Houtz, et al., 1975; Bukry, 1978, 1979, 1980a, 1980b; Martini, 1982; Ivanik, 1983; Locker and Martini, 1986; McCartney, 1987; Palmer, 1988), but this study is the first to describe common occurrences of sponge spicules in clusters.

METHODS

All core-catcher samples from the Quaternary sequences of Holes 685A (Cores 112-685A-1H through -22X) and 688A (Cores 112-688A-1H through -37X) were checked for sponge spicules in routine smear slides. From clusters of sponge spicules observed after core splitting, several specimens were

selected, spread over slides, and mounted in Canada balsam for inspection. Abundances of spicules were estimated from three traverses of 35 mm long. However, in some slides at least 10 traverses were inspected to obtain data about the diatoms *Goniothecium odontella* and *Diploneis* cf. *bomboides* that were included in the clusters. In Table 1, three classes are used to indicate the number of spicule types found: rare to few (<5%), common (5% to 25%), and abundant to dominant (>25% of the total spicule assemblage).

TERMINOLOGY

In Table 1, sponge spicules have been differentiated into megascleres, comprising monaxons and tetraxons, and microscleres. Megascleres make up the principal skeleton in Holocene sponges and are usually longer than 100 μ m. Microscleres provide an additional skeleton and are usually smaller than 100 μ m. Both categories of scleres may be subdivided into some morphotypes as a result of their function of supporting different parts of the soft body and the dermal layer (see Hartman, 1981).

Most of the sponge spicules found in the spicule clusters at Sites 685 and 688 represent megascleres; their morphologies and dimensions are shown at the top of Table 1. Within the basic types of monaxons and tetraxons, megascleres were classified into specific types of spicules (oxes, strongyles, tyles, styles, caltrops, tripods, and triaenes), which are further distinguished by prefixes, according to Schulze and Lendenfeld (1889) and Rauff (1893/1894).

Small microscleres may have been lost from most of the spicule clusters during deposition; thus, mainly some larger, but nevertheless diagnostic, spicule types (oxes, sigmas, diancisters, and asters) were noted. If possible, these types were also characterized by prefixes.

As noted above, the terminology of Schulze and Lendenfeld (1889) and Rauff (1893/1894) was adopted here to label these sponge spicules. In general, for their terminology these authors relied on Greek words, from which the Greek endings were omitted. Thus, all special terms received the same orthographic level, which contrasts with later usage, where words having deviated endings (such as chela, oxea, tylote, a.o.) and those without endings (such as strongyle, style, a.o.) were mixed to describe taxonomy (see Laubenfels, 1955; Bukry, 1978; Wiedenmayer, 1977). To accommodate common English, respective endings have been added to certain terms.

¹ Suess, E., von Huene, R., et al., 1990. *Proc. ODP, Sci. Results*, 112: College Station, TX (Ocean Drilling Program).

² Geologisch-Paläontologisches Institut der Universität, Senckenberg-Anlage 32-34, D-6000 Frankfurt am Main, Federal Republic of Germany.

³ Geologisch-Paläontologisches Institut der Universität, Olshausenstrasse 40-60, D-2300 Kiel, Federal Republic of Germany.

Sixth meeting of the **EUROPEAN UNION OF GEOSCIENCES**

Strasbourg
24 - 28 March 1991

EPISODIC MAXIMUM RESPONSE ON PRODUCTIVITY AND SEA - SURFACE- TEMPERATURES BY BENTHIC FORAMINIFERA

S. NEES

(SFB 313, University of Kiel, Olshausenstraße 40,
D-2300 Kiel, Germany)

This work is based on investigations of the benthic foraminiferal fauna and the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ ratios in two long sediment cores from the central Norwegian-Greenland-Sea. The fluctuations of the benthic foraminiferal accumulation rate (tests per $\text{cm}^2 \times 1,000 \text{ y.}$) appear to be in phase with maximum peaks of the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ curves. Although the isotopic data were measured on planktonic foraminifera the response by its benthic pendants shows a close causal connection through the whole water column.

Maxima of sea-surface-temperatures, reconstructed by $\delta^{18}\text{O}$ data, cause a distinct increase of the benthic foraminiferal accumulation rate.

These maximum peaks appear synchronously or with little time shift and with extrem high values. A use for ecological investigations seems to be obvious.

The short term "foraminiferal blooms" document optimized living conditions with an overabundant reproduction immediately followed by a wide-spread dying-off. This is closely controlled by sea-surface-conditions and productivity.

THE RELATIONSHIP BETWEEN PLANKTONIC AND BENTHIC PRODUCTIVITY BASED ON FORAMINIFERAL EVIDENCE

H. A. BAUCH and U. STRUCK

(Olshausenstraße 40, SFB 313, University of Kiel, D-2300
Kiel, Germany)

In this study three long box cores from different water masses of the Norwegian-Greenland Seas, which cover the past 500,000 years, were analysed for their benthic and planktonic foraminiferal content. The stratigraphic framework for calculating the flux rates is based on $\delta^{13}\text{C}$ -ages.

During the investigated time interval, it is shown that the faunal productivity of both the surface and bottom water environment is closely tied to the oxygen isotopic stages. This becomes even more obvious by comparing the benthic and planktonic fauna. Here, detailed correlations indicate a strong influence of the surface productivity on the benthic abundance. Bottom water currents, therefore, seem to be less important in the studied area.

Hence, stratigraphical oscillations of these productivity-sensitive faunas and their interrelation are good means for interpretations of climatically triggered events of Late Pleistocene and Recent time.

Deutsche Quartärvereinigung e. V.

* DEUQUA '92 *

12.9. - 21.9.1992 in Kiel

NEES, S. *)

Das Abbild glacialer/interglazialer Übergänge in der benthischen Foraminiferenfauna des europäischen Nordmeeres

Die bedeutendsten klimatischen Veränderungen im späten Pleistozän waren die sogenannten Terminationen, Übergänge von glazialen zu interglazialen Phasen. Um den Einfluß und die Entwicklung dieser Veränderungen in der Tiefsee zu untersuchen, wurden drei lange Sedimentkerne entlang eines Nord-Süd Transsects in der Norwegisch-Grönländischen See analysiert. Im Bereich der Terminationen wurden Proben in 2 bis 3 cm Intervallen genommen und die Gehäuse benthischer Foraminiferen ausgezählt. Im Vergleich mit den Daten aus Sauerstoffisotopen Analysen zeigen die benthischen Foraminiferen eine wesentlich deutlichere und extremere Reaktion auf die sich ändernde Umwelt. Sehr geringe Vorkommen in den Glazialen (< 10 Gehäuse pro Gramm Trockensediment = G/gr) werden von einem extremen Maximum (< 1130 G/gr) und generell hohen Vorkommen in den Interglazialen (300 - 600 G/gr), nach Konsolidierung stabiler zwischeneiszeitlicher Bedingungen, abgelöst. Dieses Maximum markiert ein wichtige Modifizierung der ökologischen Verhältnisse der Tiefsee. Während agglutinierende Foraminiferen und Infauna Arten die glaziale Fauna der Tiefsee dominieren (maximal 71%), erfahren Epifauna Arten wie *Pyrgo murrhina* (maximal 56%) und vorallem über dem Sediment angeheftete Arten, wie *Cibicides wuellerstorfi* (maximal 68%) eine regelrechte Blüte. In der zentralen Norwegischen See ist die Termination I (Sauerstoffisotopen Stadium 2 zu 1, 15 bis 8 kj vor heute) durch eine stufenweise Zunahme der benthischen Foraminiferen bis zu einem Maximum von 950 G/gr gekennzeichnet. Während der Termination II (Sauerstoffisotopenstadium 8 zu 5, 135.1 bis 125 kj vor heute) erreichen die benthischen Foraminiferen in allen Kernen das Maximum von 638 G/gr sehr rasch.

Das Auftreten benthischer Foraminiferen zeigt deutlich den starken Einfluß des Deglaziationsprozesses auf die Tiefsee. Die statischen ökologischen Bedingungen während der Glaziale bedingen stabile Verhältnisse, gekennzeichnet durch niedrigen Nährstofffluß und Arten, die an den hohen Sedimenteintrag angepaßt sind. Sobald der Eisrückzug einsetzt, sinkt aufgrund der neu initiierten Oberflächenproduktivität neuer Nährstoff durch die Wassersäule bis zum Meeresboden. Das ebenfalls neu etablierte System von Bodenströmungen sorgt für eine Verteilung der Nährstoffe in Bodennähe, wo epibenthische Foraminiferen nun ideale Lebensbedingungen vorfinden.

*) Sonderforschungsbereich 313 "Veränderungen der Umwelt: der nördliche Atlantik", Univ. Kiel

FOURTH INTERNATIONAL CONFERENCE ON PALEOCEANOGRAPHY

ICP IV

SHORT- AND LONG-TERM GLOBAL CHANGE: RECORDS AND MODELLING

21-25 SEPTEMBER 1992 KIEL/GERMANY

THE BENTHIC FORAMINIFERAL RESPONSE TO GLACIAL/INTERGLACIAL
TRANSITIONS IN A HIGH-RESOLUTION CORE SEEN AS A POSSIBLE
CHANGE IN PALAEOPRODUCTIVITY

S. Nees (Special Research Project 313, Christian-Albrechts Univ., Kiel,
Germany)

The glacial/interglacial transitions (terminations) reflect the most profound climatic changes of the Late Pleistocene. To analyze the palaeoenvironmental changes in the deep-sea for such periods three long sediment cores along a north-south transect in the Norwegian-Greenland Sea were examined in detail. Samples were taken in intervals of 3 cm and for each the benthic foraminiferal content of the sediment was counted.

In comparison with the oxygen isotope data, the benthic foraminiferal community shows a more distinct and different response to climatic and subsequently oceanographic changes. An extremely low abundance (e.g., < 10 tests per gram dry sediment = t/g) is followed by a maximum peak (e.g., < 1130 t/g) and general high abundances (300 - 600 t/g) occur after interglacial conditions are well established. This maximum peak marks a major environmental modification of the deep sea. Whereas agglutinated foraminifers and infaunal species in glacials predominate (max 71%), epifaunal species like *Pyrgo murrhina* (max. 56%) and especially clinging species like *Cibicides wuellerstorfi* (max. 68%) display apparent "blooming" conditions. In the Central Norwegian Sea at the termination I (oxygen isotope stage boundary 2/1, 15 - 8 ky bp) the benthic foraminifers show a stepwise increase in abundance going up to a maximum of 950 tests per gram dry sediment. At termination II (oxygen

isotope stage boundary 6/5, 135.1 - 125 ky bp) the benthic foraminiferal content increases in all cores and reaches a maximum peak of up to 638 t/g very rapidly.

The benthic foraminiferal community clearly displays a major impact of the deglaciation processes on the deep-sea environment. At glacials static habitat conditions on the sea floor generate a stable balance between low nutrient flux, and thus species, which are also adapted to the high sediment input. As soon as the ice cover retreats, productivity in the upper layers of the ocean near the sea surface commences (= "ice edge blooming effect") and a surplus of nutrient thus starts to travel through the water column. New initiated ocean currents then transport the nutrient down to the sea floor, where clinging benthic foraminifers and other epibenthic species thrive.



SEPM 1993 MEETING

AUGUST 8-12, 1993

PENN STATE UNIVERSITY
UNIVERSITY PARK, PA
USA

THE DYNAMIC BENTHIC FORAMINIFERAL RESPONSE TO GLACIAL/INTERGLACIAL TRANSITIONS IN NORWEGIAN- GREENLAND SEAS

S. Nees (Special Research Project 313, Kiel University, Germany)

The glacial/interglacial transitions (terminations) reflect the most profound global climatic changes of the Late Pleistocene. To analyze the impact to the environment in the deep-sea three long sediment cores along a north-south transect in the Norwegian-Greenland Sea were examined in detail. Samples were taken in intervals of 3 cm and for each the benthic foraminiferal content of the sediment was counted.

Compared with O and C isotope data, the benthic foraminiferal community shows, with respect to the deep-sea environment a more distinct and rather different response to climatic and subsequently oceanographic changes. A remarkably low abundance (e.g. < 10 tests per gram dry sediment = t/g) is followed by a maximum peak (e.g. < 1130 t/g). General high abundances (300 - 600 t/g) occur after interglacial conditions are well established. This maximum peak marks a major environmental modification of the deep sea. Whereas agglutinated foraminifers and infaunal species in glacials predominate (max 71 %), epifaunal species like *Pyrgo murrhina* (max. 56 %) and especially clinging species like *Cibicides wuellerstorfi* (max. 68 %) display apparent "blooming" conditions. At termination I (oxygen isotope stage boundary 2/1, 15-8 ky bp) in the Central Norwegian Sea the benthic foraminifers show a stepwise increase in abundance up to a maximum of 950 tests per gram dry sediment. At termination II (oxygen isotope stage boundary 6/5, 135.1-125 ky bp) the benthic foraminiferal content increases in all cores and reaches a maximum peak of up to 638 t/g very rapidly.

The benthic foraminiferal community clearly displays a major impact of the deglaciation processes on the deep-sea environment. At glacials static habitat conditions on the sea floor are generated by a stable low nutrient flux with adapted species. As soon as the ice cover retreats, productivity in the upper layers of the ocean near the sea surface commences (= "ice edge blooming effect?") and a surplus of nutrient thus starts to travel through the water column. New initiated ocean currents then transport the nutrient down to the sea floor, where clinging benthic foraminifers and other epibenthic species thrive.

Bathymetrie und Plattentektonik der Fram-Straße zwischen Grönland und Svalbard

Schlüsselregion für die geologische Geschichte der Arktis

Stephanie Pfirman, Jörn Thiede

Die Fram-Straße innerhalb der Kontinentalränder zwischen Svalbard und Ostgrönland stellt eine Tiefwasserverbindung zwischen dem Nordpolarmeer und dem Europäischen Nordmeer her und ist daher von überragender Bedeutung für die Ozeanographie dieser beiden Tiefseebecken. Heute ist die Fram-Straße eine der wichtigsten Tiefwasserstraßen des Weltmeeres, weil sie das geologisch jüngste Segment einer durchgehenden Verbindung zwischen den Kaltwassergebieten der Arktis und der Antarktis darstellt. Wassermassen,

die ihre wichtigsten hydrographischen Eigenschaften in den polaren und subpolaren Tiefseebecken und auf den angrenzenden Schelfen erhalten, können daher in niedrige Breiten einströmen und die Hydrographie des gesamten Weltmeeres prägen. Die spezielle Morphologie des Atlantischen Ozeans spielt eine besondere Rolle. Mit seiner Erstreckung über alle Klimazonen und seinen Verbindungen zu den übrigen Teilen des Weltmeeres ist der Atlantik von großer Bedeutung für das globale Ozean-Klima-System.

In den vergangenen Jahren ist eine Reihe von Übersichtskarten mit den Tiefenverhältnissen des Nordpolarmees (vgl. Abb. 1) und der angrenzenden Meeresbecken publiziert worden. Nachdem in den Jahren unmittelbar nach dem 2. Weltkrieg entscheidende Beiträge von sowjetischer Seite (Gorshkov 1980) geleistet wurden, sind die beiden heute verfügbaren wichtigsten Kartenwerke vor allem von nordamerikanischen Autoren (vgl. Abb. 1) zusammengestellt worden (Johnson et al. 1983; Perry et al. 1986). Beide Karten ähneln sich in wesentlichen Zügen, aber bei beiden sind durch die erfolgreichen Expeditionen der *Polarstern* in den Jahren 1987 und 1991 in die östlichen Teilbecken des Nordpolarmees wesentliche Diskrepanzen untereinander wie auch zu den wirklich angetroffenen bathymetrischen Verhältnissen beobachtet worden (Thiede 1988), so daß diese Kartenwerke nur sehr vereinfachte, z.T. schematische Wiedergaben der tatsächlichen Bathymetrie enthalten, die für die Zukunft noch wichtige Entdeckungen erwarten lassen. Die Ergebnisse der ARCTIC 1991 Expedition (Flüttner et al., im Druck) haben z.B. wesentliche neue Beobachtungen zur Morphologie des Amundsen-Beckens und des Lomonosov-Rückens ergeben.

Die hier benutzten Namen und geographischen Grenzen folgen der von Perry et al. 1986 herausgegebenen Karte des Nord-

polarmees, die auch die wichtigsten Elemente der Morphologie der Fram-Straße mit ihren Namen definiert. Unter Fram-Straße wird in dieser Arbeit das Gebiet in der südlichen Verlängerung des Lena-Troges, das nach Süden durch das Boreas-Becken begrenzt wird, verstanden.

Selbst so stark vereinfachte Darstellungen wie die bisher veröffentlichten Karten lassen die weiter unten im Detail beschriebene komplizierte Struktur dieses Teiles der Plattengrenze mit ihren Transformverfaltungen und den vermutlich dazwischenliegenden kurzen Segmenten des aktiven mittelozeanischen Rückens erkennen. Im Westen wird die Fram-Straße durch den dort breiten Kontinentalrand vor Ostgrönland mit der Belgica-Bank begrenzt, im Osten begleitet sie der schmale Kontinentalrand, der dem Svalbard-Archipel vorgelagert ist und durch eine komplizierte Geschichte von früh- und mitteltertiärer Tektonik der Kompression und der Transform-Bewegungen mit bedeutenden relativen lateralen Verschiebungen von Grönland und dem Barents-Schelf gekennzeichnet ist (Lawver et al. 1990).

Die Untersuchungsprogramme des deutschen Forschungseisbrechers *Polarstern* des Alfred-Wegener-Institutes für Polar- und Meeresforschung in Bremerhaven haben u.a. wichtige neue Daten zur Physiographie der Fram-Straße gesammelt, die ei-

ne wesentliche Ergänzung der bisher bestehenden Datenbasis über die Struktur des Meeresbodens in der Fram-Straße und den nördlich wie auch südlich anschließenden Tiefseebecken darstellen. In dieser Arbeit wollen wir daher versuchen,

- in großen Zügen die bisher geleistete Arbeit der geographischen Aufnahme der Fram-Straße und der angrenzenden Küstengebiete darzustellen;
- neue geowissenschaftliche Ansätze zur Beschreibung der Detailmorphologie der Fram-Straße und ihres strukturellen Aufbaus zu beschreiben;
- den Zusammenhang zwischen dem Verlauf der Grenze zwischen der eurasischen und der nordamerikanischen Platte und der daraus resultierenden Morphologie der Fram-Straße herauszuarbeiten und
- auf neue Programme zur Erforschung der Sedimentationsgeschichte in den Tiefseebecken nördlich und südlich der Fram-Straße hinzuweisen.

SIMMAX, A TRANSFER TECHNIQUE TO DEDUCE ATLANTIC SEA SURFACE TEMPERATURES FROM PLANKTONIC FORAMINIFERA - THE 'EPOCH' APPROACH.

Uwe Pflaumann¹, Josette Duprat², Claude Pujol², and
Laurent D. Labeyrie³

¹Geologisch-Paläontologisches Institut Universität Kiel,
Germany

²Département de Géologie et Oceanographie, Université de
Bordeaux 1, Talence, France

³Centre des Faibles Radioactivités, Laboratoire mixte
CNRS-CEA, Gif-sur-Yvette, France.

Submitted to "Paleoceanography"

Abstract. The CLIMAP transfer function was highly successful in generating a sea surface temperature (SST) data base that led to a revolution in the concepts of global climatic change. However, this technique suffered from significant deviations in the past species assemblages from the modern fauna, so-called 'no-analogue samples' that do not fit in the modern SST regression model and hence may produce data gaps and a reduced resolution in many SST records from the deep sea. Moreover, the selection of the faunal end members, the 'factors', as base for the regression is arbitrary or biased to some extent. Recent work by U.S. colleagues (e.g. Molino, McIntyre, Prell) overcame these problems using the Modern Analogue Technique (MAT), based on the degree of similarity between fossil and modern faunal assemblages in a specific SST field.

The new EPOCH transfer technique follows this approach and is based on a joint EPOCH set of 738 selected samples of the genuine sediment surface from the Atlantic Ocean between 87°N and 40°S, 35°E and 60°W (Figure 1). These data are linked to Levitus modern SST data for the four caloric seasons and four depth ranges. The results from the EPOCH transfer technique will provide records i) to be compared with U¹³⁷ based temperature data from the very sea surface, ii) to reconstruct the variability in the surface current regimes, iii) to estimate variations in the thickness of the ocean mixed layer, and iv) to decipher the temperature component in the planktonic $\delta^{18}O$ records for deducing paleosalinity.

**$\delta^{18}\text{O}$ TIME-SLICE RECONSTRUCTION OF MELT-WATER ANOMALIES
AT TERMINATION I IN THE NORTH ATLANTIC BETWEEN 50 AND 80 °N**

M. Sarnthein¹⁾, E. Jansen²⁾, M. Arnold³⁾, J.C. Duplessy³⁾, H. Erlenkeuser⁴⁾, A. Flatoy²⁾, T. Veum²⁾,
E. Vogelsang¹⁾ and M.S. Weinelt¹⁾

¹⁾Geologisch-Paläontologisches Institut, Universität Kiel, Olshausenstr. 40, D-2300 Kiel, Germany

²⁾Geologisk Institutt avd.B. Universitetet i Bergen, Allégaten 41, N-5007 Bergen, Norway

³⁾Centre de Faibles Radioactivités, Laboratoire mixte CNRS-CEA F-91190 Gif sur Yvette, France

⁴⁾C14-Labor, Universität Kiel, Olshausenstr. 40, D-2300 Kiel, Germany

ABSTRACT

Based on about 55 time-calibrated planktonic $\delta^{18}\text{O}$ records, we reconstructed five time slices, deciphering massive changes in surface-water paleoceanography of the Norwegian-Greenland Sea and northeastern North Atlantic across glacial Termination I. The Last Glacial Maximum (LGM; about 15,000-18,000 YBP) showed a uniformly cold Norwegian-Greenland Sea, whereas the eastern North Atlantic margin was marked by either lowered salinity, implying meltwater, or slightly increased sea-surface temperatures, suggesting a weak incursion of warm water from the south. The first deglacial meltwater event culminated about 13,600 YBP. Clockwise and counter-clockwise flow patterns are discussed for explaining the distribution of meltwater and icebergs, emanating from the Barents ice shelf. Here a second meltwater event culminated near 12,300 YBP, then linked to a clearly counter-clockwise circulation and various eddies. This current pattern continued during the Younger Dryas, which thus markedly differed from the LGM, despite the general extreme cooling. The Holocene circulation and temperature regime started near 9,000 YBP, locally still linked to weak meltwater influence. Maximum warmth was reached only about 7,000 YBP. The two meltwater

version : 08. 01. 1993

Changes in East Atlantic Deep-Water Circulation over the Last 30,000 Years - An Eight-Time-Slice Record

by Michael Sarnthein, Kyaw Winn, and Simon Jung, Geologisches Institut, University of Kiel, Germany; Jean-Claude Duplessy and Laurent Labeyrie, C.F.R., CNRS-CEA, Gif-sur Yvette, France; Helmut Erlenkeuser, C14-Labor, University of Kiel, Germany; Gerald Ganssen, Inst. voor Aardwetensch., VU Amsterdam, Netherlands.

ABSTRACT

Based on more than 90 epibenthic $\delta^{13}\text{C}$ records eight time-slices were reconstructed, which trace the distribution of East Atlantic deep and intermediate water masses over the last 30,000 years and show three modes of deep-water circulation. Near the stage 3-2 boundary the origin of NADW was similar to today. A reduced NADW flow also persisted during the Last Glacial Maximum (LGM), with constant preformed $\delta^{13}\text{C}$ values. After late Stage 3 the source region of the NADW endmember, however, shifted from the Island-Greenland Sea to areas south of Iceland. The nutrient content of NADW increased markedly near the Azores FZ from north to south, probably due to the admixture of upwelled AABW from below, then debouching much stronger into the northeast Atlantic. Later, the spread of glacial meltwater over the North Atlantic led to a marked short-term ventilation low below 1800 m about 13,500 ^{14}C y ago. The formation of NADW recommenced abruptly north of Iceland 12,800-12,500 y ago and reached an extent approaching the Holocene in the Younger Dryas. Another short-term shutdown of deep-water formation followed near 10,000-9,600 y B.P., linked to a further major meltwater pulse in the Atlantic. Each renewal of deep-water formation led to a marked release of fossil CO_2 from the ocean, the likely cause of the contemporaneous ^{14}C plateaus. Over the last 9000 y deep-water circulation varied little from today, apart from a slight maximum in AABW about 6500 y ago. The variations in the oxygenated Mediterranean Outflow were largely independent of the variations in deep-water circulation over the last 30,000 y.

Geol. Jb.	A 128	243—249	3 Abb.	1 Tab.	Hannover 1991
-----------	-------	---------	--------	--------	---------------

Die stratigraphische Verbreitung von *Siphotextularia rolshauseni* (PHLEGER & PARKER) in Sedimentkernen aus dem Europäischen Nordmeer

ULRICH STRUCK & STEFAN NEES

Bohrkern, Textulariina (*Siphotextularia*), statistische Verteilung, 018, Sauerstoffisotopen-Stadium 2,
stratigraphische Verbreitung, Pleistozän, glaziales Milieu
Norwegen-See, Grönland-See

Kurzfassung: Quantitative Untersuchungen an 12 Sedimentkernen aus dem Europäischen Nord-
meer ergaben, daß *Siphotextularia rolshauseni* nahezu ausschließlich im Sauerstoffisotopenstadium 2 vor-
kommt. Die prozentualen Häufigkeiten erreichen maximal 48%. Das Auftreten in anderen Stadien erlaubt
eine regionale Differenzierung der Kerne.

[The Stratigraphic Distribution of *Siphotextularia rolshauseni* (PHLEGER & PARKER) in Sedi-
ment Cores from the Norwegian-Greenland Sea]

Abstract: Quantitative analyses of 12 long sediment cores from the Norwegian-Greenland Sea were
carried out. Investigations show *Siphotextularia rolshauseni* as being indicative of isotopic stage 2 with a maxi-
mum of up to 48%. The occurrence in other stages allows a regional geographic subdivision of the cores.

Inhaltsverzeichnis

	Seite
1 Einleitung	244
2 Material und Methodik	244
3 Ergebnisse	246
4 Interpretation	248
5 Diskussion des Maximums im Stadium 2	248
6 Schriftenverzeichnis	248

Anschriften der Autoren: Dipl.-Geol. U. STRUCK, Dipl.-Geol. S. NEES, Sonderforschungsbereich 313, Chri-
stian-Albrechts-Universität zu Kiel, Olshausenstr. 40, D-2300 Kiel 1.

Zur Paläo-Ökologie benthischer Foraminiferen im Europäischen Nordmeer während der letzten 600000 Jahre

Ulrich Struck, SFB 313, Olshausenstraße 40, D-2300 KIEL 1

Zusammenfassung

Die fossilen Vergesellschaftungen benthischer Foraminiferen in elf Sedimentkernen aus dem südlichen Europäischen Nordmeer wurden qualitativ und quantitativ untersucht. Sauerstoffisotopenstratigraphie war die Grundlage für die Datierung der Kerne, wobei gut definierte biostratigraphische Leit Horizonte zur Absicherung der Sauerstoffisotopenstratigraphie genutzt wurden. 42 Arten benthischer Foraminiferen wurden sicher bestimmt und 5 Artengruppen definiert. Die wichtigsten Arten der fossilen Faunen der letzten 600000 Jahre sind *Oridorsalis umbonatus* (REUSS), *Cibicides wuellerstorfi* (SCHWAGER), *Cassidulina teretis* TAPPAN, *Triloculina tricarinata* d'ORBIGNY und *Pyrgo rotalaria* LOEBLICH & TAPPAN. Biostratigraphische Horizonte bilden *Siphonotextularia rothauseni* PHLEGER & PARKER, *Pullenia bulloides* (d'ORBIGNY) und *Globocassidulina subglobosa* (BRADY). Die meisten Interglaziale sind gut abgegrenzt durch das Vorkommen von *C. wuellerstorfi*. Die Berechnung von Individuenakkumulationsraten (INDAR) hat gezeigt, daß die Produktivität benthischer Foraminiferen in den Interglazialen meist drei bis vier mal höher ist als in Glazialen. Vier Phasen mit deutlich erhöhter INDAR zeigen hochproduktive Phasen im Europäischen Nordmeer an. In diesen Abschnitten (entspr. Isotopensubstadien 11.3, 9.3, 7.1 und 5.5.1) sind geographischen Verteilungsmuster durch einen deutlichen Gradienten von Südosten mit den höchsten INDAR mit abnehmender Tendenz nach Norden und Westen ausgebildet. Durch Faktorenanalyse konnte bestätigt werden, daß Schwankungen abiotischer Parameter wie Korngröße, Gehalt an organischem Kohlenstoff und Kalziumkarbonat keine bedeutende Auswirkung auf die Gemeinschaft benthischer Foraminiferen der letzten 600000 Jahre zeigen. Die Interpretation von Habitatansprüchen der fossilen Faunen hat gezeigt, daß sich im Europäischen Nordmeer nur in den Interglazialen dominante filtrierende Epifaunen etabliert haben. In den Glazialzeiten dominierten detritivore Epi-/Endofauna-Arten. Dies wurde in den Zusammenhang gesetzt mit einer nur in den Interglazialen wirkenden Advektion von Nahrungspartikeln durch laterale Bodenströmungen. Laterale Strömungen wurden ausgeschlossen in Glazialzeiten, wo detritivore Epi-/Endofauna dominierte. Diese Ergebnisse wurden interpretiert als Anzeiger für die An- oder Abwesenheit der thermohalinen Zirkulation, die die Bodenströmungen im heutigen Europäischen Nordmeer speist.

Abstract

Eleven long sediment cores from the Norwegian Greenland Sea have been investigated on their benthic foraminiferal content. Oxygen isotopic stratigraphy was the basic method to date the cores with the help of biostratigraphic marker-horizons. 42 benthic foraminiferal species were found and 5 taxonomic groups were described. The most important species during the past 600000 years are *Oridorsalis umbonatus* (REUSS), *Cibicides wuellerstorfi* (SCHWAGER), *Cassidulina teretis* TAPPAN, *Triloculina tricarinata* d'ORBIGNY and *Pyrgo rotalaria* LOEBLICH & TAPPAN. Stratigraphic useful layers are marked by *Siphonotextularia rothauseni* (PHLEGER & PARKER) (in Stage 2), *Pullenia bulloides* (d'ORBIGNY) (in Substage 5.1) and *Globocassidulina subglobosa* (BRADY) (in Substage 11.3). Interglacial conditions are well documented by high amounts of *C. wuellerstorfi*. The calculation of 'individual-accumulation-rates' (INDAR) shows three or four times higher foraminiferal productivity in interglacial periods than in glacial. Four high productivity events were observed in INDAR results. These periods (located in substage 11.3, 9.3, 7.1 and 5.5.1) show a regional strongly reducing faunal content from southeastern parts of Norwegian Greenland Sea with highest amounts to lower INDAR northern- and westernmost. The interpretation of fossil habitats shows a distinct dominance of suspension-feeding epifauna during interglacial periods. Glacial periods are dominated by detritivore epi-/endofaunal foraminifers. These results have been connected with the recent bottom current system, which is the transport mechanism of feed material for suspension-feeders. Horizontal currents can therefore be precluded during glacial times. This could be interpreted as indicator for the 'Thermohaline Circulation System' in Interglacials.

Early decay of the Barents Shelf Ice Sheet – spread of stable isotope signals across the eastern Norwegian Sea

MARA S. WEINELT,
MICHAEL SARNTHEIN,
ELKE VOGELSANG &
HELMUT ERLKENKEUSER

Weinelt, M. S., Sarnthein, M., Vogelsang, E. & Erlenkeuser, H.: Early decay of the Barents Shelf Ice Sheet – spread of stable isotope signals across the eastern Norwegian Sea. *Norsk Geologisk Tidsskrift*, Vol. 71, pp. 137–140. Oslo 1991. ISSN 0029-196X.

Based on planktonic $\delta^{18}\text{O}$ records from 16 sediment cores obtained from the Norwegian Sea, we traced a meltwater signal marking the onset of Termination I. From its discharge point south of Bear Island, it spread alongshore the Norwegian margin up to 63°N , thereby suggesting a clockwise-directed drift of icebergs and surface water in the Norwegian Sea, the opposite of the present circulation pattern.

Mara S. Weinelt, Michael Sarnthein & Elke Vogelsang, Department of Geology, Olshausenstr. 40; Helmut Erlenkeuser, ^{14}C Laboratory, University of Kiel, 2300 Kiel, Germany. Correspondence to Michael Sarnthein, Geologisch-Paläontologisches Institut, Olshausenstrasse 40, 2300 Kiel, Germany.

Jones & Keigwin (1988) and Lehman et al. (1991) presented the first AMS- ^{14}C dated oxygen-isotope evidence from the Fram Strait suggesting that the marine-based Barents Shelf Ice Sheet had disintegrated rapidly about 14,500–13,500 years ago. This melting process occurred very early in the chain of deglacial events during Termination IA.

Based on seven sediment cores with high average sedimentation rates (8–100 cm/1000 years) (Table 1) from the Bear Island sediment fan and nine cores with medium high to low sedimentation rates from the

central Norwegian Sea and the Fram Strait (1.5–15 cm/1000 years) (Fig. 1), we were able to map the oxygen and carbon isotope signals of the planktonic foraminifer *N. pachyderma* l.c., signals linked to this catastrophic event, and to identify the source and the probable regional distribution pattern of the meltwater spike, as defined by its $\delta^{18}\text{O}$ amplitude (Fig. 2).

Oxygen isotope measurements from sediment records with medium to high resolution (e.g. cores 23258 to 23262) suggest that the meltwater event ($\delta^{18}\text{O}$ shift) of the Barents Ice Sheet immediately succeeded the

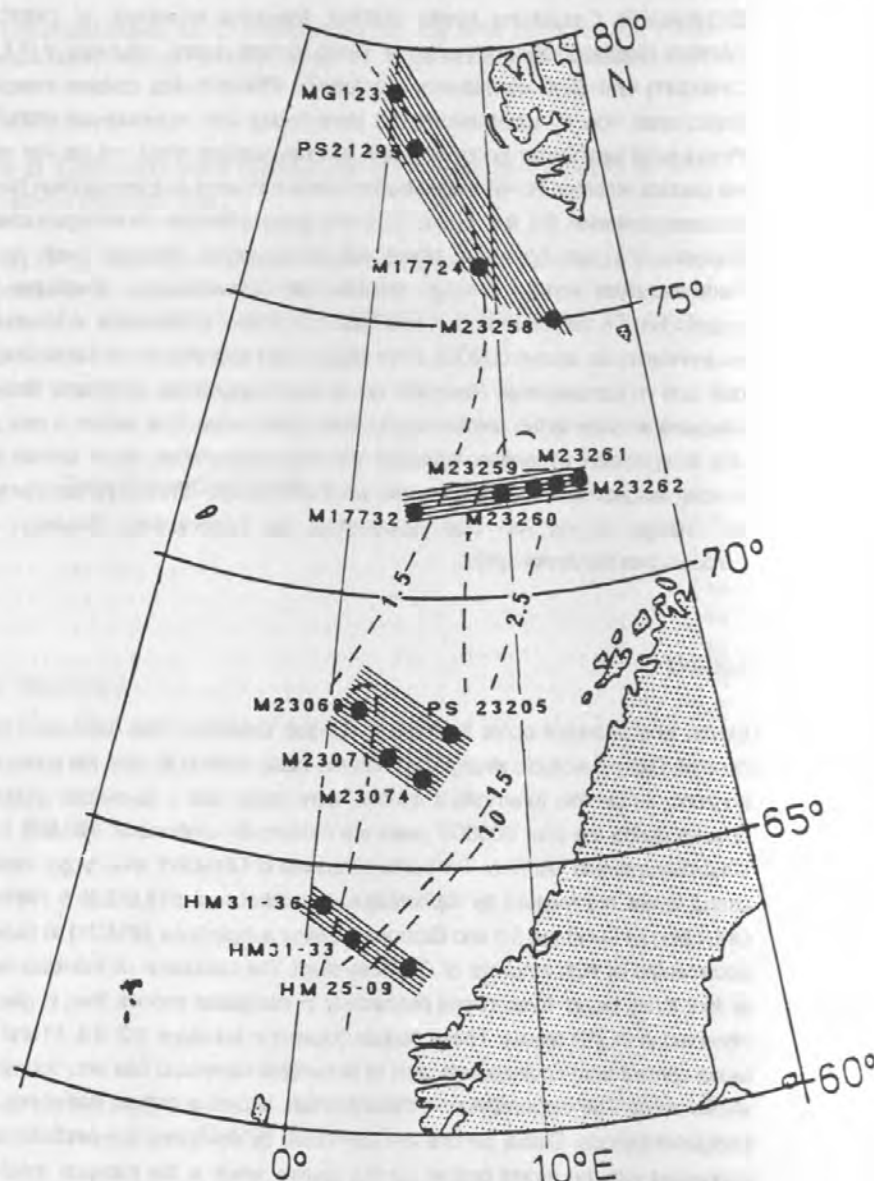


Fig. 1. Core locations in the Norwegian Sea. Contours mark $\delta^{18}\text{O}$ amplitudes (in per mille) of meltwater signal.

VERÄNDERUNGEN DER OBERFLÄCHENZIRKULATION IM EUROPÄISCHEN NORDMEER WÄHREND DER LETZTEN 60.000 JAHRE - HINWEISE AUS STABILEN ISOTOPEN.

DISSERTATION ZUR ERLANGUNG DES DOKTORGRADES DER MATHEMATISCH-NATURWISSENSCHAFTLICHEN FAKULTÄT DER CHRISTIAN-ALBRECHTS-UNIVERSITÄT ZU KIEL

VORGELEGT VON
MARA WEINELT

KIEL 1993

ZUSAMMENFASSUNG

Mithilfe von hochauflösenden stabilen Isotopenkurven wurde die wechselnde zeitliche und räumliche Verbreitung der Oberflächenwassermassen im Europäischen Nordmeer für die letzten 60.000 Jahre rekonstruiert. Die Identifizierung gleichaltriger O- und C-Isotopensignale in ca. 60 Tiefseekernen beruht auf einer verfeinerten Regional-Stratigraphie, die anhand von 12 absolut datierten Isotopenkurven entwickelt wurde.

Es zeigte sich, daß instabile paläo-ozeanographische Verhältnisse die Zeiträume von 55.000-25.000 (^{14}C -) J.v.h. (Isotopenstadium 3) und von 15.000-10.000 (^{14}C -) J.v.h. (Eiszeitermination I) prägten. Wiederholt lassen sich in diesen Zeitspannen niedrigrisalinare Wasserkörper auskartieren, die durch das Abschmelzen großer Eisbergscharen entstanden und im Extremfall eine Umkehr der Oberflächen-Strömung und ein ästuarines System zwischen Nordmeer und Nordatlantik bewirkten (z.B. vor 13.500 und vor 55.000 Jahren). Umgekehrt konnte aber in Stadium 3 und in Termination I immer wieder salzreiches atlantisches Wasser weit in das Nordmeer eindringen, das unter winterlicher Abkühlung zu einer Tiefenkonvektion führte (z.B. vor 26.000 Jahren und in der Jüngerer Dryas)

Im Wesentlichen stabile ozeanographische Verhältnisse prägten das Nordmeer hingegen während des Letzten Glazialen Maximums und im Holozän seit 9.000 (^{14}C) Jahren, als sich das heutige anti-ästuarine Strömungssystem mit Oberflächeneinstrom und Tiefenwasserauström etablierte. Im ebenfalls weitgehend stabilen LGM erstreckte sich im zentralen Nordmeer eine homogene, vollsaline Wassermasse, während der östliche NE-Atlantik durch eine ausgedehnte Schmelzwasseranomalie bestimmt wurde. Die Umschwünge von einem zum anderen Strömungsregime erfolgten dabei in Zeitspannen, die die Auflösung der ^{14}C -Datierung unterschreiten.

History of terrigenous sedimentation during the past 10 m.y. in the North Atlantic (ODP Legs 104 and 105 and DSDP Leg 81)

Thomas C.W. Wolf and Jörn Thiede

GEOMAR Research Centre for Marine Geosciences, Christian Albrechts University, Wischhofstrasse 1–3, Building 4,
D-2300 Kiel 14, FRG

(Received March 1, 1990; revision accepted September 21, 1990)

ABSTRACT

Wolf, T.C.W. and Thiede, J., 1991. History of terrigenous sedimentation during the past 10 m.y. in the North Atlantic (ODP Legs 104 and 105 and DSDP Leg 81). In: T.O. Vorren, H. Sejrup and J. Thiede (Editors), *Cenozoic Geology of the Northwest European Continental Margin and Adjacent Deep Sea Areas*. Mar. Geol., 101: 83–102.

Bulk sediment measurements and analyses of the input of $>63\ \mu\text{m}$ terrigenous particles have enabled us to reconstruct the variability of sediment flux in the Norwegian and the Labrador seas as a function of paleoceanographic and paleoclimatic changes.

In both areas, minor amounts of coarse terrigenous particles occur in sediments that were deposited between 9.5 and 7.0 Ma. The higher amounts are only documented in the Norwegian Sea around 5.7–5.4 Ma. Variations in bulk sediment accumulation are related to a strengthening of Denmark Strait Overflow, which is closely connected with the production of Norwegian Sea Deep Water between 8.3 and 7.8 Ma, 6.9 and 6.1 Ma and 5.3 and 4.2 Ma. In the Labrador Sea, reduced bottom water activity coincided with the highest levels of organic carbon accumulation and an increase in bulk sediment accumulation, and may correlate with the latest Miocene Messinian Event.

In both the Labrador Sea and the Norwegian Sea a drastic increase in the amount of coarse terrigenous particles (rock fragments and quartz) started at around 4.0 Ma, recording a nearly simultaneous onset of large-scale ice rafting. This was ultimately caused by a deterioration in the northern hemisphere climate, possibly related to the final closure of the Isthmus of Panama.

Marine Geology, 99 (1991) 187–207
Elsevier Science Publishers B.V., Amsterdam

Late Pleistocene sedimentation on the Norwegian continental slope between 67° and 71°N

S.H. Yoon^a, S.K. Chough^a, J. Thiede^b and F. Werner^b

^aDepartment of Oceanography, Seoul National University, Seoul 151-742, Korea

^bGeomar-Forschungszentrum für Marine Geowissenschaften, Wischhofstrasse 1–3, D-2300 Kiel, FRG

(Received May 14, 1990; revision accepted January 7, 1991)

ABSTRACT

Yoon, S.H., Chough, S.K., Thiede, J. and Werner, F., 1991. Late Pleistocene sedimentation on the Norwegian continental slope between 67° and 71°N. Mar. Geol., 99: 187–207.

The northern Norwegian continental margin between 67° and 71°N comprises the gentle slope off the Barents Sea, the relatively steep Lofoten Islands slope, and the step-like slope of the Voring Plateau. During the late Pleistocene, these slopes received large amounts of terrigenous sediments from an extensively glaciated Norwegian continental margin. Through the analyses of 17 gravity cores, high-resolution (3.5 kHz) and airgun seismic profiles, and Sea-Beam bathymetric data, we have examined the late Pleistocene sedimentation pattern of this region.

Eight sedimentary facies from the gravity core analysis and seven types of 3.5 kHz echo characters indicate that the slopes were moulded by hemipelagic sedimentation commonly associated with iceberg rafting, slope failure (slump/slide and debris flow), turbidity currents, downslope bottom currents, and contour-following bottom currents. Ice-rafted debris was dispersed over a broad area, including the lower slopes off the Barents Sea and the Lofoten Islands, and the Voring Plateau and its outer slope. Slope failures prevailed on the Lofoten Islands and Voring Plateau slopes where the broad glacial margin directly released unsorted glacial sediments during glacial periods. On the Barents Sea slope, glacial and reworked shelf sediments were supplied by underflows which were probably caused by cooling of surface shelf water during glacial periods; on the upper slope sediments were further transported by turbidity currents and slope-crossing bottom currents which excavated numerous small-scale channels. There are indications of deep-sea contour currents at the base of slope and the upper slope off the Barents Sea, and on the Voring Plateau. These currents probably resulted from water exchange between the Norwegian–Greenland Sea and the North Atlantic Ocean during interglacial periods.

Kurzfassungen

TERRA

abstracts

Abstract supplement No. 1 to *TERRA nova*, Volume 5, 1993

EUG VII
Strasbourg,
France
4 - 8 April 1993

Synoptical studies of Holocene pelagic and benthic communities of the Rockall Plateau

H. Andruleit, A. Baumann, S. Fu[#], S. Jung, A. Kohly,
S. Nees, and A. Schröder

(Sonderforschungsbereich 313, [#]Geologisches
Institut und Museum, Christian-Albrechts-
Universität Kiel, D-2300 Kiel, Germany)

The composition of nanno- and microfossil communities express paleo-climatic changes and its subsequent paleo-oceanographic reaction. In a high resolution sampling density (2 - 5 cm) the Holocene sediments of core 23414 were analysed for its fossil record (planktic and benthic foraminifera, radiolarians, dinoflagellate cysts, diatoms and coccolithophorids), the oxygen isotope ratio of *N. pachyderma* and *Cibicides wuellerstorfi* and sedimentary structures.

The results of the oxygen isotope investigations reveals a reliable stratigraphy with an average sedimentation rate. The bulk carbonate content increases from low glacial values up to 80 % in modern samples. The total accumulation rate, the abundance of particular species and the relationship of the pelagic and benthic groups may reflect the vertical marine coupling processes in the water column. All groups show a significant change in composition and accumulation rate since the last deglaciation. These results prove a changing trophic quality of the surface water masses and an increasing organic matter flux. Prediagenetic processes (e.g. solution in aggressive porewater) were taken into consideration with regard to sensitive fossil tests. The x-ray radiographs show a very low impact of bioturbate action.

HOLOCENE PLANKTON ASSEMBLAGES IN THE NORTH ATLANTIC: A COMPARISON OF THE COCCOLITHOPHORID-DIATOM-DINOFLAGELLATE-RADIOLARIAN ASSOCIATION ON A SOUTH-NORTH TRANSECT

H. Andruseit (Special Research Project 313, Kiel, Germany),
A. Baumann, A. Kohly, and A. Schröder

The plankton assemblages comprising coccolithophorids, diatoms, dinoflagellates, and radiolarians have been investigated in five box/piston cores of late Pleistocene to Holocene age. The cores are located on a transect from Rockall Plateau to west off the Barents Shelf following the main route of the North Atlantic drift and the Norwegian current.

An identical set of samples has been used to define the temporal and spatial distribution of the different groups in order to evaluate changes in the paleo-environment since Termination I.

The four groups are compared to study the environmental parameters of the coexistence and syn-ecology of plankton communities in a pelagic realm. Thus, the recent association and the assemblages in the sediments are considered synoptically to obtain a most complete record of their common development.

Variations in accordance to latitude and core depth can be seen at all four groups reflecting environmental changes. Absolute abundancies and diversities show similar trends in the northern part of the transect, whereas in the south the distribution patterns are more complicated.

Coccolithen als Anzeiger für die klimatische Entwicklung der letzten 1 mio. Jahre im Nordatlantik

Baumann, K.-H.

GEOMAR, Forschungszentrum für marine Geowissenschaften,
Wischhofstr. 1-3, Geb. 4, D-2300 Kiel 14

Das Vorkommen von Coccolithen in Sedimenten des Nordatlantiks variiert stark in Abhängigkeit von den klimatischen Verhältnissen. Im Europäischen Nordmeeres sind sie hauptsächlich in interglazialen Sedimenten zu finden, kommen in diesen Zeitabschnitten aber auch im angrenzenden Nordatlantik in sehr viel größeren Häufigkeiten vor. Innerhalb der Interglaziale werden prinzipiell gleichartige Abfolgen, gekennzeichnet durch sukzessives Einsetzen und Ausscheiden verschiedener, an unterschiedliche Temperaturbereiche angepaßter Arten festgestellt, die analoge Klimaabläufe in den verschiedenen Interglazialzeiten belegen.

In den verschiedenen Interglazialen werden die Gemeinschaften jedoch durch unterschiedliche Arten dominiert. Dieses ist einerseits auf jeweils unterschiedliche ökologische Bedingungen, aber auch auf die Evolution der Gephyrocapsaceae zurückzuführen. Coccolithen der Gattung *Gephyrocapsa* dominieren die Gemeinschaften der untersuchten quartären Ablagerungen.

Gephyrocapsa zeigt eine morphologische Entwicklung, die bei den meisten anderen Arten nicht beobachtet wird. Daher sind Arten biometrisch untersucht worden, von denen angenommen werden kann, daß sie ökologisch stabil geblieben sind, um so ein zusätzliches Hilfsmittel für die Interpretation palökologisch-ozeanographische Veränderungen zu erhalten.

Es zeigt sich, daß die Coccolithen von *C. pelagicus* in ihrer Größe, wahrscheinlich in Abhängigkeit von den ökologischen Bedingungen, deutlich variieren. Wesentlich kleinere Coccolithen (um bis zu 25%) werden im statistische Mittel in den Zeitabschnitten beobachtet, in denen diese Art einen dominierenden Anteil an der Gemeinschaft ausmacht.

Größenunterschiede werden auch bei Coccolithen von *C. leptoporus* festgestellt. Die beobachteten, schon in früheren Arbeiten beschriebenen, Varietäten werden als Okophänotypen derselben Art interpretiert. Auch in den untersuchten Sedimentproben lassen sich unterschiedliche ökologische Abhängigkeiten der beiden Varietäten verdeutlichen.

II. GEM Workshop, Global *Emiliana* Modelling Initiative, Blagnac, Frankreich, 21.-26. September 1991.

Coccolithophore Communities, Coccoliths Sedimentation and Coccolith Assemblages in the Norwegian-Greenland Sea

K.-H. Baumann

(GEOMAR Research Center for marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 1)

Coccolithophores constitute a significant part of the epipelagic phytoplankton. Variations in occurrence and species frequency appear to depend on ecological conditions in near-surface water masses. Coccoliths, their skeletal elements, are a main component of the pelagic carbonate and these coccolith assemblages are often used for paleoecological and paleoceanographic reconstructions. But more actuopaleontological background information is necessary for ecological and oceanographic interpretations of coccolith distributions in areas like the Norwegian-Greenland Sea.

Therefore, the living and fossil plankton associations from a series of selected stations in the northern North Atlantic have been and will be studied in order to examine

- the distribution and composition of the coccolithophore communities and their bloom phases,
- the particle transport through the water column and changes in the biocoenosis,
- the particle sedimentation and changes in the thanatacoenosis,
- and the temporal and spatial distribution of coccoliths in the late Quaternary.

Preliminary analyses have shown that coccolithophores are one of the main Phytoplankton groups in the Norwegian-Greenland Sea. They occur in large cell densities (up to 300,000/l) in the epipelagic realm and approximately 20 species have been identified. The largest number of species occur in the area of the warm Norwegian Current, away from which the numbers gradually decrease to the north and west towards the arctic waters. All of the species take part in blooms, but the largest portion of the high cell counts in the bloom phases consists of *Emiliana huxleyi* (up to 80% or more).

Isolated coccoliths were found floating in the water column at all depths. But *E. huxleyi* and *Coccolithus pelagicus* are the only species making up floating coccolith assemblages in the lower part of the water column. *C. pelagicus* generally increases in frequency with greater depths in most of the transects due to its high corrosion resistance.

The coccolith accumulations in deep sediment traps (4-500m above the seafloor) also contained almost entirely these two species. Their proportions dominated the flux of both nannoplankton carbonate and numbers of individual coccoliths. The coccolith flux recorded in the sediment traps displayed a time-lag of one to two month with respect to phytoplankton productivity in the euphotic zone. This can be accounted for by the estimated sinking interval of fecal pellets and macroaggregates, which represent the main downward transport mechanism for coccoliths.

Samples from the sediment surface contain significantly less coccolithophorid species than are included in living communities in the same area. *E. huxleyi* and *C. pelagicus* make up the main portion of coccolith assemblages in the surface sediments. Additionally *Calcidiscus leptoporus* and *Gephyrocapsa muelleri* were regularly found in small amounts only. This becomes even more remarkable when one consider the fact that this two species are rarely found in the living communities. The ratios of the two dominant coccolith species in surface sediments reflects the various water masses in the Norwegian-Greenland Sea. While *E. huxleyi* makes up more than 80% below the Norwegian Current, *C. pelagicus* becomes dominant in the Arctic area.

The occurrence of coccoliths in late Quaternary sediments of the Norwegian-Greenland Sea varies with climatic conditions. High abundances of coccoliths are present during interglacial times, whereas intervals with very sparse occurrences represent glacial conditions. With the help of the variability of calcareous nannoplankton communities, ecological differences between individual interglacials can be described.

Morphometrical variations of Quaternary *Coccolithus pelagicus* coccoliths from northern North Atlantic and their paleoceanographical implications

K.-H. BAUMANN

(GEOMAR Research Center for marine Geosciences, Kiel, Germany)

Consistent variations in the morphometrical distribution patterns of *Coccolithus pelagicus* coccoliths are observed in upper Quaternary sediments of the Norwegian-Greenland Sea. In general, the distal shield of *C. pelagicus* coccoliths show a wide range of size variations, typically 8-16 μm in length and 6-14 μm in width. Element count for the distal shield is 30-65. Length, width, and the number of distal shield elements are strongly correlated to each other. This indicates that coccolith size can be determined by the length alone.

The coccolith assemblages in sediments of the Norwegian-Greenland Sea are drastically influenced by glacial-interglacial climatic changes. *C. pelagicus* occurs in high abundances only during oxygen isotope stage 7 and during the Holocene. Within these intervals there is a drastic decrease in size while the interspecific proportions do not change. Although all samples contain specimens up to 15 μm the absolute majority is 8-12 μm in length. Assemblages from below and above these intervals only contain larger specimens (generally >10 μm).

Investigations of *C. pelagicus* coccolith size variations in surface sediments of the northern North Atlantic show that a decrease in size of the proximal shield occurred towards the north. Whereas on the Rockall Plateau a wide range of size variations occur, the bulk of specimens are always <12 μm in length in the Norwegian-Greenland Sea. In contrast, in sediments from the Fram Strait only very small coccoliths (7-11 μm) were observed. Thus, it can be inferred that variations in size and abundance of this species seems to reflect ecological differences on a genetically unchanged population.

**7th Meeting of European Union of Geosciences (EUG VII),
Straßburg, April 4-8, 1993**

**Glacial history of the Scandinavian Ice Sheet: A marine-
terrestrial correlation**

K.-H. Baumann¹, R. Henrich¹, K. Lackschewitz¹, R. Spielhagen¹,
T.C.W. Wolf¹ and J. Mangerud²

(¹GEOMAR, Research Center for Marine Geosciences,
Wischhofstr. 1-3, D-2300 Kiel 14, Germany)

(²Univ. Bergen, Dept. of Geology, Sect. B, Allég. 41, N-5007
Bergen, Norway)

Late Pleistocene climatic changes are observed in seven deep-sea sediment cores from the Norwegian Sea by investigating variations in calcium carbonate content versus amount of coarse terrigenous detritus. Glacial and interglacial cycles reveals a number of terrigenous particle events as well as differentiated calcium carbonate production which can be correlated to major paleoclimatic shifts. Time control is based on high-resolution oxygen isotope stratigraphy of all analyzed sediment cores. The deep-sea sediments of the Norwegian Sea contain layers with high contents of terrigenous detritus and low amounts of calcium carbonate. These layers record marked decreases in sea surface temperature and salinity, decreases in the flux of biogenic carbonate, and massive discharges of icebergs. The composition of the coarse terrigenous detritus indicate that most of the debris was derived from Scandinavia. Therefore, variations in the terrigenous particle input appear to be the result of oscillations of the Scandinavian Ice Sheet. A simplified model of the Scandinavian Ice Sheet variations during the last 130,000 years correlates well with the marine data. Thus, the phases with an increased input of ice-rafted detritus reflect repeated advances of the Scandinavian Ice Sheet. Since the dating of the terrestrial record of Scandinavia is still uncertain, this correlation will also improve the age assignments to the individual glacial events.

VARIATIONS IN ICE RAFTED TERRIGENOUS INPUT AND CARBONATE FLUX IN NORWEGIAN-GREENLAND SEA IN RESPONSE TO CLIMATIC CHANGE DURING THE LAST 350,000 YEARS.

K.-H. Baumann, B. Jünger, K. Lackschewitz, R.F. Spielhagen, T.C.W. Wolf, R. Henrich
(GEOMAR, Research Center for Marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 14, Germany)

Late Pleistocene climate changes are observed in twenty long sediment cores from entire Norwegian-Greenland Sea (NGS) and Fram Strait by investigating variations in calcareous biogenic versus coarse terrigenous input. Time control is based on high-resolution oxygen isotope stratigraphy of all analyzed cores.

Detailed studies on the composition and distribution of terrigenous components in the coarse fraction (125-500µm) show important episodic fluctuations which reflect variations in ice rafting. Generally high amounts of lithogenic material in glacial sediments from the eastern and central NGS reflect enhanced deposition of coarse ice rafted detritus (IRD) indicating that melting of ice occurred in this area. Carbonate content is highest in peak interglacials (e. g. oxygen isotope stages 1, 5.1, 5.5), indicating maximum intrusion of warm Atlantic surface waters.

In contrast, northern Greenland Sea and Fram Strait sediments from peak interglacials and also from intervals of maximum glaciation (e. g. stages 1, 2, 5.5, 5.1, 6.2) are characterized by relatively low amounts of coarse terrigenous material. Relatively high carbonate contents indicate only little dilution by fine grained terrigenous material and a minimum of ice melting. However, during times of intermediate conditions, terrigenous input was strongly dominating and carbonate flux was extremely low, indicating extensive ice melting and IRD-deposition.

Regional and spatial variability of these parameters allows the reconstruction of changes in surface current systems, ice covers and biologic productivity in the Norwegian-Greenland Sea and Fram Strait in response to global climatic changes.

**ICP IV - Fourth International Conference on
Paleoceanography, Kiel, 21.-25. September 1992.**

**CLIMATIC CHANGE IN THE NORWEGIAN-GREENLAND SEA
AND FRAM STRAIT DURING THE LAST 300,000 YEARS: ICE
RAFTED TERRIGENOUS INPUT VERSUS CARBONATE
FLUX.**

K.-H. Baumann, B. Jünger, K. Lackschewitz, R.F. Spielhagen,
T.C.W. Wolf, R. Henrich (GEOMAR, Research Center for
Marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 14,
Germany)

Late Pleistocene climate changes are observed in twenty long sediment cores from entire Norwegian-Greenland Sea (NGS) and Fram Strait by investigating variations in calcareous biogenic versus coarse terrigenous input.

Time control is based on high-resolution oxygen isotope stratigraphy of all analyzed cores. Detailed studies on the composition and distribution of terrigenous components in the coarse fraction (125-500 μ m) show important episodic fluctuations which reflect variations in ice rafting.

Generally high amounts of lithogenic material in glacial sediments from the eastern and central NGS reflect enhanced deposition of coarse ice rafted detritus (IRD) indicating that melting of ice occurred in this area. Carbonate content is highest in peak interglacials (e. g. oxygen isotope stages 1, 5.1, 5.5), indicating maximum intrusion of warm Atlantic surface waters.

In contrast, northern Greenland Sea and Fram Strait sediments from peak interglacials and also from intervals of maximum glaciation (e. g. stages 1, 2, 5.5, 5.1, 6.2) are characterized by relatively low amounts of coarse terrigenous material. Relatively high carbonate contents indicate only little dilution by fine grained terrigenous material and a minimum of ice melting. However, during times of intermediate conditions, terrigenous input was strongly dominating and carbonate flux was extremely low, indicating extensive ice melting and IRD-deposition.

Regional and spatial variability of these parameters allows the reconstruction of changes in surface current systems, ice covers and biologic productivity in the Norwegian-Greenland Sea and Fram Strait in response to global climatic changes.

Late Quaternary continental glaciations and bioproductivity in the Norwegian-Greenland Sea area: The marine sediment record.

Baumann, K.-H., Jünger, B., Lackschewitz, K.S., Spielhagen, R.F., Wolf, T.C.W. & Henrich, R.
(GEOMAR, Research Center for Marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 14, Germany)

Variations in calcium carbonate content versus amount of coarse terrigenous detritus in sediment cores provide evidence for the impact of Late Quaternary climatic changes on continental glaciations and biogenic calcium carbonate productivity in the Norwegian-Greenland Sea area. Time control is based on high-resolution oxygen isotope stratigraphy and AMS- ^{14}C .

Deep-sea sediments of the Norwegian-Greenland Sea contain layers with high contents of terrigenous detritus and low amounts of calcium carbonate. These layers are time equivalent to repeated advances of the Scandinavian and Svalbard Ice Sheets and record marked decreases in sea surface temperature, decreases in the flux of biogenic carbonate, and massive discharges of icebergs. Their composition indicates that most of the debris was derived from Scandinavia and the Svalbard/Barents Sea region. Thus, continental ice advances are reflected by high amounts of ice-rafted detritus.

High calcium carbonate contents indicate the inflow of warm Atlantic surface water. Inflow of the North Atlantic Current was strongest in the Norwegian Sea during peak interglacials and decreased towards the north and the west. Low but constant values in the westernmost cores document a relatively stable environment during the last 300,000 years. Weak influences of warm surface water masses were present only during interglacials. Deposition of terrigenous detritus also decreased towards the west and to the north, most probably due to a relatively high stability of the Greenland Ice Sheet and little ice melting.

LATE QUATERNARY CALCIUM CARBONATE SEDIMENTATION AND TERRIGENOUS INPUT ALONG THE EAST GREENLAND CONTINENTAL MARGIN

BAUMANN, K.-H., LACKSCHEWITZ, K.S., ERLLENKEUSER, H.,
HENRICH, R., JÜNGER, B. & KASSENS, H.

GEOMAR, Research Center for Marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 14, Germany

Abstract

Nine giant gravity corer collected in the western Greenland-Iceland-Norwegian (GIN) Sea were analyzed for calcium carbonate content and coarse fraction component records. Stratigraphic control is based on oxygen isotope records performed on four of the cores. All cores have been correlated to each other based on fluctuations in calcium carbonate content, coarse terrigenous particle content and the occurrence of volcanic ash beds.

Glacial and interglacial cycles are documented by a number of terrigenous particle events and differentiated calcium carbonate production which can be correlated to major paleoceanographic and paleoclimatic shifts. Major shifts in terrigenous input and pelagic carbonate records were identified close to stage 9/8 and 6/5 boundaries and within early stage 1. High ratios of ice-rafted lithic fragments were observed especially at the end of glaciations close to the Terminations, indicating the melting of massive influxes of icebergs into the western GIN Sea. These enormous inputs of debris were followed by a drastic increase in calcium carbonate production caused by maximum intrusion of warm Atlantic surface waters. Relatively high calcium carbonate contents also shows that only little dilution by fine grained terrigenous material and a minimum of ice melting occurred.

Extensive IRD deposition occurred until about isotope stage 9 and document a relatively stable environment in this area, strongly influenced by relatively cold surface water masses. The following interval was characterized by more variable changes in the general surface water circulation pattern, although high amounts of IRD are still present in Iceland Sea sediments. During stage 5, conditions were more uniform indicating a less pronounced westward penetration of Atlantic waters as compared to the Holocene. A distinct contrast between the northernmost cores and the cores in the south is indicative of a rather strong westward Atlantic water influx in the north and of a cold water dominated area east of the Kolbeinsey Ridge during the Holocene. However, conditions west of Jan Mayen seem to have remained constantly dominated by cold surface waters throughout the whole time investigated.

Second Annual Workshop PONAM: Polar North Atlantic Margins, Late Cenozoic Evolution, Hanstholm, Dänemark, 25.-28. November 1991.

LATE QUATERNARY CARBONATE SEDIMENTATION AND TERRIGENOUS INPUT ALONG THE EAST GREENLAND CONTINENTAL MARGIN

K.-H. Baumann, K.S. Lackschewitz & R. Henrich

GEOMAR, Forschungszentrum für marine Geowissenschaften, Wischhofstr. 1-3, D-2300 Kiel 14, Germany

Eight large box cores collected in the western GIN-Sea were studied for carbonate content and coarse fraction components. Stratigraphic control is based on oxygen isotope records performed on three of the cores. Based on the fluctuations of calcium carbonate content and the occurrence of volcanic ash beds the eight cores are correlated. Major stratigraphic boundaries are dated according to these correlations with isotopically dated cores. Additional biostratigraphic information is provided by benthic foraminifera *Pullenia bulloides* (Orbigny) showing a peak abundance near the end of isotopic stage 5.

Calcium carbonate distribution of surface sediments reflect the present major surface water circulation pattern. Relatively high carbonate contents are observed in the central and northern Greenland Basin underlying warmer surface water masses, whereas west of Jan Mayen and on the Kolbeinsey Ridge only very low carbonate values have been measured indicating relatively cold surface water masses.

Calcium carbonate are rare to abundant in the sediment surface samples with highest abundances (>30 wt.-%) over parts of the central GIN Sea and decreasing abundances towards the Greenland continental margin. Highest carbonate values are found where a branch of the Norwegian Atlantic Current enters the Iceland Sea and Greenland Sea contributing to the East Iceland Current and Jan Mayen Current. Lowest carbonate values occur in the western GIN Sea sediments underlying the cold East Greenland Current. The Jan Mayen Current transport small amounts of polar water in region of the Jan Mayen Fracture Zone indicated by low carbonate values.

Sediment cores from the Kolbeinsey Ridge are characterized by generally low carbonate values with low amplitudes and does not have a high carbonate zone at the top. Highest

contents of carbonate are observed in oxygen isotope stage 5 indicating an intensified inflow of relatively warm North Atlantic water into this region.

Cores west of Jan Mayen are characterized by the lowest carbonate values and the lack of an obvious carbonate pattern. This makes precise dating and correlating of the cores difficult. The situation recorded here represents uniform paleoceanographic conditions in this area during the last two glacial-interglacial cycles. These conditions were only interrupted by a very short incursion of warmer water indicated by the short increase in carbonate content during oxygen isotope stage 5.

The carbonate variations in cores of the central and northernmost Greenland Basin reflect a spatially and temporally more differentiated surface water circulation. Carbonate values and amplitudes are higher than in the southern part of the studied area. On the contrary to the southern cores, highest carbonate contents are observed in the Holocene sediments, whereas carbonate levels corresponding to oxygen isotope 5 are more equal in height to the carbonate contents of the cores from Kolbeinsey Ridge.

Detailed studies on the composition and distribution of the terrigenous components in the coarse fraction (125-500 μ m) show important episodic fluctuations which reflect variations in ice-rafting. In general, glacial age sediments contain layers with high amounts of lithogenic material. These layers result from deposition of ice rafted debris produced by the melting of this ice. Highest accumulation of terrigenous material are found in levels corresponding to the end of glacial stages 6 and 2. Its rapid and drastic decreases during or shortly after stage 6/5 and 2/1 transitions point to the onset of inflowing warm North Atlantic surface waters into the western GIN-Sea.

DAS ABBILD DER ZIRKUM-ARKTISCHEN EISSCHILDE IN SPÄTQUARTÄREN SEDIMENTEN DES EUROPÄISCHEN NORDMEERES

Baumann, K.-H., Lackschewitz, K.S., Spielhagen, R.F., Wolf, T.C.W. & R. Henrich (GEOMAR, Forschungszentrum für marine Geowissenschaften, Wischhofstr. 1-3, 2300 Kiel 14)

Die Sedimentationsgeschichte des Europäischen Nordmeeres stand im Quartär unter dem unmittelbaren Einfluß der großen Inlandeisschilde. Während der Kaltzeiten hat sich der skandinavische Eisschild mehrfach bis weit nach Mitteleuropa ausgedehnt und anschließend zurückgezogen, während das Festlandseis über Grönland im Verhältnis dazu relativ stabil geblieben ist. Wenn das Inlandeis die damalige Küstenlinie erreichte, wurden große Mengen von Eisbergen in den Ozean freigesetzt, die erodiertes Gesteinsmaterial enthielten. Der wechselnde Gehalt an eistransportiertem Material (IRD) in den Tiefseesedimenten stellt somit ein Abbild der Entwicklungsgeschichte der zirkum-arktischen Eisschilde dar.

Für diese Untersuchung wurden 17 Sedimentkerne aus dem Europäischen Nordmeer sedimentologisch bearbeitet. Neben der Bestimmung der IRD-Gehalte wurde an allen Kernen der biogene Kalziumkarbonatanteil ermittelt. Die zeitliche Einstufung der Sedimente aller Kerne wurde mittels hochauflösender Sauerstoffisotopen-Stratigraphie erreicht.

Es lassen sich Abfolgen von Terrigen- und Karbonat-"Ereignissen" beobachten, die weitgehend den Glazial- und Interglazialzyklen entsprechen und mit Änderungen in der Paläo-Ozeanographie und dem Paläoklima korreliert werden können. Hohe Gehalte an grobem terrigenem Material in glazialen Sedimenten des Europäischen Nordmeeres spiegeln das vermehrte Abschmelzen von Meer- und Gletschereismassen wider. Dagegen deuten hohe Karbonatanteile auf den Einstrom von warmen atlantischen Oberflächenwassermassen hin.

Auffällig hohe IRD-Ablagerungen während der Glaziale und der Abschmelzphasen werden besonders im Bereich der Norwegischen See beobachtet. Dagegen ist in der Grönland und Island See, vor allem während des Zeitabschnittes 180 - 125 ka, nur relativ wenig IRD abgelagert worden. Grund hierfür ist wahrscheinlich die relativ hohe Stabilität des grönländischen Eisschildes und die damit verbundenen geringeren Abschmelzraten.

Die petrographische Zusammensetzung des IRD in Kernen aus dem östlichen und zentralen Europäischen Nordmeer zeigt, daß der überwiegende Anteil des terrigenen Materials von Skandinavien angeliefert wurde. Daher muß angenommen werden, daß Änderungen im Terrigeneintrag durch Oszillationen des skandinavischen Eisschildes hervorgerufen wurden. Die im Modell von Mangerud (1991) dargestellten Änderungen in der Ausdehnung des skandinavischen Eisschildes während der letzten 130 ky lassen sich außerordentlich gut mit den hier vorgestellten IRD-Daten korrelieren.

Mangerud, J. (1991): The last interglacial/glacial cycle in northern Europe. - In: Shane, L.C.K. & Cushing, E.J. (Hrsg.); Quaternary Landscapes; Minneapolis, S. 38-75

**Sea Level Changes, Processes and Products -
82nd Annual Meeting of the Geologische
Vereinigung, Stuttgart, 26.-29. Februar 1992.**

**HOLOCENE COCCOLITH AND DINOFLAGELLATE CYST
ASSEMBLAGES IN SEDIMENTS FROM NORWEGIAN
SEA**

K.-H. BAUMANN & J. MATTHIESSEN

(GEOMAR, Forschungszentrum für marine Geowissen-
schaften, Wischhofstr. 1-3, D-2300 Kiel 1)

Coccolith and dinoflagellate cyst assemblages have been investigated in five sediment cores from the Norwegian-Greenland Sea. Both fossil groups are characterized by similar composition. The assemblages are of low diversity and contain high proportions of single species. The coccolith flora consists almost entirely of *Coccolithus pelagicus* and *Emiliania huxleyi*. The dinoflagellate cysts are generally dominated by *Operculodinium centrocarpum* and *Nematosphaeropsis labyrinthica*. Other species sometimes contribute considerable to the assemblages.

Based on the concentration and diversity of the assemblages and the ratio changes between the dominating species it has been possible to establish three distinct steps of major paleoceanographic changes. Sparse occurrences of coccoliths and dinocysts have been observed before 10,000 yrs B.P., indicating harsh environmental conditions with dominant influence of meltwater and very small inflow of Atlantic water. The surface-water circulation pattern was reinitiated after the Termination I_B. The assemblages suggest slightly cooler conditions than today with a similar circulation pattern until 7,500 yrs B.P.. A considerable change in composition of coccolith and dinocysts assemblages occurs corresponding approximately to the onset of the Holocene climatic optimum. Since 6,000 yrs B.P. the Norwegian current with its modern oceanographic and ecological properties was completely established.

Variations in surface water mass conditions in the Norwegian Sea: Evidence from Holocene coccolith and dinoflagellate cyst assemblages

K.-H. Baumann and J. Matthiessen

GEOMAR, Research Center for Marine Geosciences, Wischhofstraße 1–3, D-2300 Kiel 14, Germany

(Received January 31, 1992; revision accepted September 9, 1992)

ABSTRACT

Baumann, K.-H. and Matthiessen, J., 1992. Variations in surface water mass conditions in the Norwegian Sea: Evidence from Holocene coccolith and dinoflagellate cyst assemblages. *Mar. Micropaleontol.*, 20: 129–146.

Coccolith and dinoflagellate cyst assemblages have been investigated in five sediment cores from the Norwegian Sea and Fram Strait. Both fossil groups are characterized by similar patterns of composition. The assemblages contain high proportions of single species. The coccolith flora is of low diversity and consists almost entirely of *Coccolithus pelagicus* and *Emiliania huxleyi*. The dinoflagellate cysts are generally dominated by *Operculodinium centrocarpum* and *Nematosphaeropsis labyrinthus*. Other species, especially *Bitectatodinium tepikiense*, *Peridinium saeroense* and *Impagidinium pallidum*, sometimes contribute considerably to the assemblages.

Based on the abundance of the assemblages and the ratio change between the dominating species it has been possible to establish three intervals of distinct major changes in surface water mass conditions. Sparse occurrences of coccoliths and dinoflagellate cysts have been observed before 10,000 yrs B.P., indicating harsh environmental conditions with a distinct influence of meltwater and temporarily very slight inflow of Atlantic water. The modern surface-water circulation pattern was reinitiated during Termination I_B. The assemblages suggest slightly cooler and probably less saline surface water conditions than are present today until 7500 yrs B.P. Solar insolation may have caused a first temperature peak which is responsible for the early Holocene productivity maximum. A considerable change in the composition of dinocyst and coccolith assemblages occurs corresponding approximately to the onset of the Holocene climatic optimum. This change was most probably linked to an almost synchronous reorganization of the hydrographic properties in the entire North Atlantic realm after the ice sheets had vanished. Since 6000 yrs B.P. the Norwegian Current with its modern oceanographic and ecological properties has been fully established.

Introduction

The Norwegian–Greenland Sea is an area of remarkable meridional and zonal hydrographical contrasts in surface water conditions. Relatively warm and saline North Atlantic water penetrates across the Iceland–Scotland Ridge forming the Norwegian Current, which cools substantially on its way north and then sinks

and flows as a subsurface current into the Arctic Ocean. Cold, less saline, seasonally ice-covered polar waters intrude from the Arctic Ocean through the Fram Strait (Fig. 1), forming the East Greenland Current. Arctic surface water masses cover the central part of the Greenland and Iceland Sea, forming the Arctic domain (Swift, 1986), which consists of Atlantic and Polar waters.

Phytoplankton, especially coccolithophorids and diatoms, are a sensitive indicator of these environmental conditions (cf. Paasche, 1960; Samtleben and Bickert, 1990; Samtle-

Correspondence to: K.-H. Baumann, GEOMAR, Research Center for Marine Geosciences, Wischhofstraße 1–3, Building 4, D-2300 Kiel 14, Germany.

ABRUPT PALEO-CLIMATIC AND -OCEANOGRAPHIC INTERACTIONS IN THE NORWEGIAN SEA SINCE 1 Ma (ODP-LEG 104 SITE 643)

**BAUMANN, K.-H., WOLF, T.C.W. & THIEDE J., (GEOMAR
Research Center for marine Geosciences at Christian-Albrechts University,
Wischhofstraße 1-3, Bldg. 4, D-2300 KIEL 14, F.R.G.)**

One of the goals of global change research is the study of basic components which control paleoceanographic and paleoclimatic variations and which are able to explain the evolution of oceanographic and climatic changes during the past 1 my. Stable oxygen isotopes (*N. pachyderma* sin.), calcareous nannofossils, anorganic- and organic carbon content and coarse terrigenous particle analyses have been investigated in sediments of ODP LEG 104 Site 643 (Norwegian Sea) since 1 Ma. Sampling intervals of 5 to 10 cm have been used to represent time intervals of 2500 years, enabling us to establish a high-resolution oxygen isotope stratigraphy. The calculation of accumulation rates provides the opportunity to reconstruct variations in sediment mass balances which can then be used as recorders of global paleoclimatic and paleoceanographic events. Several periods of abrupt and drastic sediment mass balance variations can be distinguished in the Norwegian Sea and will be synthesized as long- and short-term interactions of paleoceanography and paleoclimate.

Aix-en-Provence: 8th International Palynological Congress, 6.9. -12.9.92

BIEBOW, N. & MATTHIESSEN, J.: Poster: Dinoflagellate cyst assemblages from Recent sediments offshore Peru and east Greenland, Programm and Abstracts, 14.

DINOFLAGELLATE CYST ASSEMBLAGES FROM RECENT SEDIMENTS OFFSHORE PERU AND EAST GREENLAND

BIEBOW, Nicole and MATTHIESSEN, Jens
Research Center for Marine Geosciences, Kiel University, Wischhofstr. 1-3, D-2300 Kiel 14, Germany

Recent dinoflagellate cyst assemblages from the upwelling region offshore Peru (5-10°S, 80-85°W) have been compared with assemblages from Scoresby-Sound, East Greenland (70-71°N; 20-28°W). Both environments are characterized by strongly contrasting surface water conditions. The upwelling region is influenced by warm temperate water masses (T=15,8-18°C; S=35,0-35,5 PSU) whereas the Scoresby-Sound is dominated by polar water masses (T= 0-2°C; S=26,0-31,0 PSU) which are most of the year ice-covered.

The dinoflagellate cyst assemblages have been analyzed both quantitatively and qualitatively. Peridiniacean dinoflagellate cysts always contribute considerable to the assemblages in both environments. The occurrence of different morphotypes of peridiniacean dinoflagellate cysts, especially of the genus *Brigantedinium*, show that these cysts may be useful proxy-indicators of extreme hydrographic conditions, such as upwelling or ice-cover.

BAUMANN, A. & MATTHIESSEN, J.: Poster: Late Quaternary dinoflagellate cyst assemblages from Rockall Plateau to Fram Strait, Program and Abstracts, 10.

LATE QUATERNARY DINOFLAGELLATE CYST ASSEMBLAGES FROM ROCKALL- PLATEAU TO FRAM STRAIT

BAUMANN, Astrid ¹ and MATTHIESSEN, Jens ²

¹SFB 313, Kiel University, Heinrich-Hecht-Platz 10, D-2300 Kiel 1, Germany

²Research Center for Marine Geosciences, Kiel University, Wischhofstr. 1-3, D-2300 Kiel 14, Germany

Dinoflagellate cyst assemblages have been investigated in several box cores containing Holocene and late glacial sediments. These cores are located on a transect from Rockall-Plateau to Fram Strait which is influenced by surface water of the North-Atlantic Drift and Norwegian Current.

The surface water masses show a wide range in temperature from about 15 to 4°C in August and 10 to -1°C in February along the transect. Salinities are more uniform and range from 35,3 to 35,1 PSU, with the exception of salinities in Fram Strait which only reach 34,5 PSU.

The temporal and spatial distribution of the dinoflagellate cyst assemblages has been described in order to evaluate changes in the paleoenvironment since Termination I. The assemblages are dominated by few species. *Impagidinium* spp., *N. labyrinthus* and *O. centrocarpum* are always important components of these assemblages.

Unlike most assemblages *?I. pallidum* achieves higher percentages in sediments from Fram Strait.

The dinoflagellate cyst record will be compared with other planktic microfossils (radiolarians, diatoms, coccolithophorids and foraminifers) to obtain a complete and distinct record of surface water changes in late glacial and Holocene times.

MATTHIESSEN, J.: Vortrag: Distribution patterns of Recent dinoflagellate cysts in Norwegian-Greenland Sea sediments. Program and abstracts, 100.

DISTRIBUTION PATTERNS OF RECENT DINOFLAGELLATE CYSTS IN NORWEGIAN-GREENLAND SEA SEDIMENTS

MATTHIESSEN, Jens

Research Center for Marine Geosciences, Kiel University, Wischhofstr. 1-3, D-2300 Kiel 14, Germany

Dinoflagellate cysts have been examined in surface sediments from the Norwegian-Greenland Sea. This environment is characterized by remarkable hydrographical contrasts in surface water conditions. Relatively warm and saline North Atlantic waters pass across the Iceland-Faeroe Ridge forming the Norwegian Current on the east side of the Norwegian Sea which cools substantially on its way north and then sinks and flows as a subsurface current into the Arctic Ocean. Cold, less saline, seasonally ice-covered polar waters intrude from the Arctic Ocean through the Fram Strait into the Greenland Sea, forming the East Greenland Current. Arctic surface water masses, which consist of Atlantic and polar waters cover the central part of the Greenland and Iceland Sea.

The distribution of individual species and assemblages is related to the bathymetry and oceanography of the Norwegian-Greenland Sea. Oceanographic fronts separating the polar, arctic and Atlantic water masses appear to be biogeographical boundaries both for individual species and assemblages. Thus, single assemblages are restricted to certain surface water masses in the Norwegian-Greenland Sea. This has also been shown for calcareous and siliceous microfossil assemblages such as planktic foraminifera, coccoliths and diatoms. The occurrence of most cyst species is related to the warm Atlantic surface waters.

The distribution patterns of individual species suggest that even on a small scale hydrographic features such as branches of cold waters transported from the East Greenland Shelf eastward can be recognized in the distribution patterns of individual species.

Dinoflagellaten-Zysten in spätquartären Sedimenten des Europäischen Nordmeeres

Jens Matthießen (GEOMAR, Kiel)

Das Europäische Nordmeer stellt ein relativ engräumiges Sedimentationsbecken dar, das durch deutliche hydrographische Kontraste in den Oberflächenwassermassen charakterisiert wird. Der Ostgrönlandstrom transportiert kalte, meereisbedeckte polare Wassermassen (Temperaturen unter 0°C , Salinitäten geringer als $34,4^{\circ}/\text{‰}$) nach Süden, während durch den Norwegenstrom relativ warme, nordatlantische Wassermassen (Temperaturen höher als 3°C , Salinitäten größer als $34,9^{\circ}/\text{‰}$) nach Norden gelangen. Im zentralen Teil des Europäischen Nordmeeres existieren im wesentlichen zwei zyklonale Wirbel, die durch nach Osten bzw. Westen driftende polare und atlantische Wassermassen erzeugt werden. Diese arktischen Wassermassen können saisonal mit Meereis bedeckt sein und weisen Temperaturen zwischen $0-4^{\circ}\text{C}$ und Salinitäten um $34,6-34,9^{\circ}/\text{‰}$ auf.

Palynologische Untersuchungen zeigen, daß die Verbreitung von Dinoflagellaten - Zysten und Acritarchen in den rezenten Sedimenten in Beziehung zu diesen Oberflächenwassermassen stehen. Mit Hilfe der Faktorenanalyse lassen sich 4 Gemeinschaften definieren, die jeweils eine deutliche Präferenz für bestimmte Wassermassen aufweisen. Kalte polare Wassermassen werden durch *Algidasphaeridium minutum* und runde braune protoperidinoide Zysten (überwiegend *Brigantedinium* spp.) charakterisiert. *Impagidinium pallidum* und *Nematosphaeropsis labyrinthus* dominieren in den Sedimenten unter den arktischen Wassermassen. Relativ warme nordatlantische Wassermassen werden durch *Operculodinium centrocarpum* gekennzeichnet. Auf den Schelfen vor Nordisland und Norwegen dominiert *P. faeroense* die Gemeinschaften. Weitere Arten zeigen ebenfalls deutliche Präferenzen für bestimmte Wassermassen, wobei die höchste Diversität der Gemeinschaften in den Sedimenten unter den atlantischen Wassermassen erreicht wird.

Das Vorkommen von Dinoflagellaten-Zysten in Sedimentkernen ermöglicht es, die paläo-ozeanographische Entwicklung des Norwegenstromes in den letzten 15.000 Jahren zu rekonstruieren. Mit Ausnahme kurzer Zeitschnitte mit vermutlich erhöhtem Schmelzwassereintrag haben nordatlantische Wassermassen immer die hydrographischen Eigenschaften der Oberflächenwassermassen beeinflusst. Mit Hilfe des Phytoplanktons läßt sich zeigen, daß jedoch erst vor 6000-7000 Jahren der Norwegenstrom seine heutigen hydrographischen Eigenschaften erhielt.

THERMAL EVOLUTION OF NORTH ATLANTIC SURFACE WATER MASSES OVER THE LAST 200 KA - GEOCHEMICAL AND MICROPALAEONTOLOGICAL INDICATIONS

D. Nürnberg (Alfred Wegener Institute, Bremerhaven, Germany) & K.-H. Baumann

The geochemical and paleontological investigations of deep-sea sediment cores located along a N-S-trending profile in the northernmost North Atlantic and the Norwegian-Greenland Sea indicate new aspects in the paleoceanographic development of the Norwegian Current.

Geochemical analyses on fossil tests of the planktonic foraminifer *Neogloboquadrina pachyderma* sin. reveal that magnesium in foraminiferal tests reflects relative surface water temperature changes. Since the incorporation is uninfluenced by salinity changes of surface waters, magnesium provides an exclusively "thermal" signal. Studies on coccoliths in the Norwegian-Greenland Sea reveal that abundances strongly vary in accordance to climatic changes. Coccoliths are mainly restricted to interglacial core sections, indicating variable oceanographic regimes through time.

The combination of quantitative coccolith data and magnesium in foraminiferal tests makes a differential paleoceanographic reconstruction of the Norwegian Current possible. Significant magnesium variations in *N. pachyderma* sin. during isotopic stages 6 and 3 characterize a more variable surface-water circulation than previously assumed. At the beginning of stage 5, the drastic increase of magnesium concentrations accompanied by a successive appearance of various coccolith species indicates the starting influx of relatively warm North Atlantic surface masses. In accordance to coccolith data, magnesium data indicate an establishment of the Norwegian Current even during substages 5.3 and 5.1, whereas during substages 5.4 and 5.2, a drastic cooling of surface waters and/or a complete reduction of inflowing North Atlantic surface water occurred. For the glacial stages 4 and 2, the interruption of inflowing surface waters has to be considered due to very low magnesium concentrations. The climatic change to the Holocene is reflected both in a drastic increase in magnesium concentrations and high coccolith abundances indicating a severe of relatively warm North Atlantic surface water amasses. During Termination 1A, these surface waters presumably reached Vøring Plateau, but established in the Fram Strait not before Termination 1B.

Living coccolithophore communities in the northern North Atlantic

C. SAMTLEBEN¹ & K.-H. BAUMANN²

(¹Geol.-Pal. Inst., Univ. Kiel, Germany)

(²GEOMAR Research Center for marine Geosciences, Kiel, Germany)

Since 1987 investigations of living coccolithophore communities have been carried out to record occurrence, distribution, and abundances of species in the northern North Atlantic. Up to now, a set of more than 200 plankton samples from about 80 stations have been examined. According to coccolithophore occurrences and abundances three species groups can be distinguished in the Norwegian-Greenland Sea as a result of specific ecological preferences:

(1) A relative varied "Atlantic Group" which, above all, contains species of the Syracosphaeraceae (*Syracosphaera borealis*, *S. corolla*, *S. molischii*) and holococcolith bearing forms (e.g. *Corisphaera gracilis*). They were found primarily at stations within the Norwegian Current at temperatures above 9-10°C. Only a few of these species tolerate slightly cooler conditions.

(2) An "Arctic Group" that is distinctly less varied also inhabits the relatively warm Norwegian Current but extends further westward into the area of Arctic mixed surface water. This group is heterogeneous as well and not equally distributed: While *Algirosphaera robusta* and *Ophiaster hydroideus* are found primarily in areas with prominent Atlantic water influence, *Emiliana huxleyi*, *Alisphaera unicornis*, and *Calciopappus caudatus* can be observed up to directly on the polar front.

(3) A "Polar Group" that is composed only of the two cold-adapted species *Coccolithus pelagicus* and *Papposphaera sagittifera*. These species do occur in the Norwegian Current, but their primary area of distribution is within Arctic water which is colder than 6°C. *C. pelagicus* was almost always found in the resting stage as well as in the motile phase, the *Cristallolithus hyalinus* stage, without significant differences in cell numbers.

Moreover, south of the Iceland-Scotland Ridge there is a varied coccolithophore community of the North Atlantic which first of all contains *E. huxleyi*, species of the genus *Gephyrocapsa* (*G. muelleriae*, *G. ericsonii*), *Syracosphaera* (e.g. *S. orbiculus*, *S. protrudens*, *S. pulchra*) and holococcolithophorid species (e.g. *Calyptrorpha oblonga*, *Zygosphaera bannockii*, *Calyptrolithophora papillifera*). Parts of this group are drifted to the northern regions of the Norwegian-Greenland Sea in late summer. The generally northward decrease in species number can primarily be explained by the limiting influence of water temperatures.

The coccolithophore communities are subject to strong seasonal variations that lead to big differences between summer and winter/spring. Thereby, the abundances of single species change within the regional groups, producing strong blooms mainly by the species *E. huxleyi* in summer (> 3 mill. cells/liter). The seasonal variations of the species groups shift to the north/north-west with the drift of the Atlantic surface water masses. While south of Iceland first blooms occur in May/June, a high cell density is observed in the region of the Vøring Plateau in July, near Bear Island in August, and west of Jan Mayen not until September. The vertical flux of coccolithophorid material corresponds to these observations. In deep sediment traps in the Lofoten Basin and near Bear Island sedimentation maxima of coccoliths are observed one month after the main production phases in surface waters.

Besides, distinct variations between the observation years have been revealed by our investigations. These differences include composition and species abundances of the regional species groups as well as time and intensity of production phases. However, there is always a close connection between the distribution of the regional species groups and the different water masses.

**ICP IV - Fourth International Conference on
Paleoceanography, Kiel, 21.-25. September 1992.**

**LIVING COCCOLITHOPHORE COMMUNITIES IN THE
NORWEGIAN-GREENLAND SEA AND THEIR DISTRIBUTION
IN SURFACE SEDIMENTS**

C. Samtleben¹, K.-H. Baumann, A. Schröder
(¹ Geol.-Paläont. Institut, Univ. Kiel, Olshausenstr. 40, D-2300
Kiel 1, Germany)

Epipelagic coccolithophore communities have been investigated in a series of plankton samples which have been taken together with salinity and temperature measurements during five cruises to the Norwegian-Greenland Sea since 1988. Abundance and species diversity of coccoliths in surface sediments have been examined in 75 samples of the entire Norwegian-Greenland Sea.

Living coccolithophore communities in the Norwegian-Greenland Sea can be classified in three regional groups tracing the corresponding surface water masses: (1) an Atlantic group, (2) an Atlantic-Arctic group, and (3) an Arctic group. These assemblages are decomposed and altered during descent in the water column. Destruction and solution of delicate heterococcoliths and of all the holococcoliths leave only few species at deeper water levels. These species are further influenced by differential dissolution and destruction at the sediment-water interface.

As a result, the original composition of the living communities becomes increasingly obscured in the impoverished taphocoenoses. Samples from surface sediments contain significantly less coccolithophorid species than those which are included in living communities of the same area. However, based on their concentration and diversity and the ratio changes between *Emiliania huxleyi* and *Coccolithus pelagicus* it was possible to establish biogeographic zones. Thus, the coccolith distribution in surface sediments of the Norwegian Sea seems to give a good description of the various locations of various water masses in the area.

Coccoliths in Sediment Traps from the Norwegian Sea

CHRISTIAN SAMTLEBEN and TORSTEN BICKERT

Geologisch-Paläontologisches Institut, Universität Kiel, Olshausenstr. 40–60, D-2300 Kiel (F.R.G.)

(Received February 14, 1989; revised and accepted August 29, 1989)

Abstract

Samtleben, C. and Bickert, T., 1990. Coccoliths in sediment traps from the Norwegian Sea. *Mar. Micropaleontol.*, 16: 39–64.

The fine fraction of surface sediment samples in the Norwegian Sea shows an unexpectedly high amount of calcareous nannoplankton. Investigations, using time-series sediment traps in the Lofoten Basin (69°N, 1983/84), near Bear Island (75°N, 1984/85) and in the Fram Strait (78°N, 1984/85) provided information about the accumulation of this material in relation to the strong seasonality of biological production.

Coccolith identification and counting, by means of a scanning electron microscope, indicated that the coccolith assemblages in the traps consist almost entirely of the two species *Emiliania huxleyi* and *Coccolithus pelagicus*. These species dominated the flux rate of the nannoplankton carbonate. A further eight species only made minor contributions to the flux.

In the Lofoten Basin a distinct seasonality could be recognized in both standing crop and carbonate flux. Also the relationship between the two main species and the proportion of intact coccospheres showed an annual cycle. In the sample series of the two northerly traps the seasonality was less distinct. In general, the coccolith flux decreases towards the North. This was particularly evident for the smaller species *E. huxleyi*, while the number of massive *C. pelagicus* coccoliths — and so the coccolith carbonate flux — diminished only slightly.

Additional investigations on water samples from the Norwegian Sea revealed species compositions that differed greatly from those in the sediment traps. This suggests that selective processes change the relative species proportions during sedimentation.

Introduction

The Norwegian Sea is characterized by strong seasonal changes which are mainly controlled by cycles of insolation, water temperature, and ice cover. These seasonal changes result in variations in the biological productivity that are associated with different groups of organisms. The sedimentation in this oceanic region is interconnected with biological productivity and is also influenced by oceanographic conditions.

The surface sediments in the Norwegian Sea, on the Vøring Plateau and in the Lofoten Basin consist for the most part of calcareous nannofossils and can be described as a coccolith ooze

(See Plate III, 4). The fact that, in a number of places, this sediment has been observed to extend for several tens of centimeters to the Holocene/Pleistocene boundary, indicates the considerable significance of coccolithophorids to the post-glacial sedimentation of this region. To date however, little work has been done either on the relationship between the production of biogenic particles and their sedimentation, or on the mechanisms of their transport to the seafloor.

Investigations using sediment traps that were begun in 1983 in a joint program of the Woods Hole Oceanographic Institution and the Universities of Kiel and Bremen (Honjo et al.,

Living coccolithophore communities in the Norwegian–Greenland Sea and their record in sediments

Christian Samtleben and Andrea Schröder

Geologisch-Paläontologisches Institut, Universität Kiel, Olshausenstraße 40–60, D-2300 Kiel, Germany

(Received July 1, 1991; revision accepted March 16, 1992)

ABSTRACT

Samtleben, C. and Schröder, A., 1992. Living coccolithophore communities in the Norwegian–Greenland Sea and their record in sediments. *Mar. Micropaleontol.*, 19: 333–354.

Investigation of epipelagic coccolithophore communities along a transect from the Vøring Plateau (off Norway) to Scoresbysund (East Greenland) and comparison with coccolith assemblages in underlying surface sediments reveal that sedimentation of coccoliths is dependent on the following factors: (1) Composition of the coccolithophore communities and their bloom phases, (2) grazing and selective destruction by zooplanktonic organisms, (3) type of vertical flux in fecal pellets, and (4) varying carbonate dissolution in different water masses. Dissolution increases towards the boundaries of carbonate sedimentation. As a result, the original composition of the living communities becomes increasingly obscured in the impoverished taphocoenoses. However, differential resistance to dissolution of the two primary calcareous nannoplankton species *Emiliana huxleyi* and *Coccolithus pelagicus* is such that occurrence and ratio of the two species in surface sediments reflect the various water masses in the Norwegian–Greenland Sea.

Introduction

Coccolithophores constitute a significant part of phytoplankton in the epipelagic (i.e. photic) zone of the oceans. Variations in occurrence and species frequency appear to depend on ecological conditions in near surface water masses such as water temperature, light intensity, nutrient content, and water movement. Coccoliths in Late Quaternary sediments from the Norwegian–Greenland Sea have been used for paleo-oceanographic and ecostratigraphic studies by Eide (1987), Gard (1988) and Baumann (1990). However, investigation of coccolith material from sediment traps and comparison with living coccolithophore communities from the Norwegian–Greenland Sea reveal significant differences in occurrence and species frequencies (Samtleben and Bickert, 1990). Obviously, alongside phytoplankton production, zooplankton activities and redeposition processes are involved in coccolith sedimentation and effect an alteration of the species composition in the sediment by selective destruction of a part of the flora.

With the present study we intend to analyse the information content of coccolith assemblages in Recent sediments of the Norwegian–Greenland Sea specifically with respect to the following questions:

(1) How are living coccolithophore communities correlated to surface water masses?

(2) How are living coccolithophore communities altered during descent through the water column?

Correspondence to: C. Samtleben, Geologisch-Paläontologisches Institut, Universität Kiel, Olshausenstraße 40–60, D-2300 Kiel, Germany.

Response to climatic changes in the Norwegian Sea: Pleistocene plankton and terrigenous sediment records (ODP-Leg 104 Site 643)

Wolf, T.C.W., Baumann, K.-H., Schulz, M. & Thiede, J.
(¹GEOMAR, Research Center for Marine Geosciences, Wischhofstr. 1-3, D-2300 Kiel 14, Germany)

The Norwegian Sea is a key region for understanding the development of glacial/interglacial climatic changes in the Northern Hemisphere. These changes have drastically affected the polar and subpolar regions of the Northern Hemisphere, creating variable oceanographic gradients. To obtain a high-resolution record, stable oxygen isotopes (*N. pachyderma* sin.), coccoliths, anorganic and organic carbon content, and coarse terrigenous particle analyses have been investigated in sediments from ODP Leg 104 Site 643 (Norwegian Sea) since 1 Ma. Sampling intervals of 5 to 10cm have been used to represent time intervals of 2500 years, enabling us to establish a high-resolution oxygen isotope stratigraphy.

Several periods of abrupt and drastic sediment balance variations can be distinguished in the Norwegian Sea. An increased abundance of coccoliths and planktic foraminifers documents time intervals of strong Atlantic surface water intrusions into the Norwegian Sea especially during oxygen isotope stages 5, 11, 13, 15, whereas during stages 7 and 9 coccolith data record a much weaker Atlantic water influence. The same trend can be observed in the bulk accumulation rate of calcium carbonate. It is remarkable that the abundance of coccoliths decreases between 1.0 and 0.6 Ma. On the other hand terrigenous particle input reflects time intervals of clear glacial conditions during stages 2, 4, 6, 8, 10, 12, 14. A continuous input of these particles is revealed between 1.0 and 0.6 Ma, indicating - together with decreasing abundances of coccoliths during this timespan - limited Atlantic surface water transport into the Norwegian Sea.

In addition, terrigenous particle input is clearly related to the orbital frequencies in the Milankovitch band, with mean periods of 100, 41, and 21 kyr for the past 0.6 Ma.

SEDIMENTATION IN THE NORTHERN NORTH ATLANTIC

B. J. Haupt, C. Schäfer-Noth, D. Seidel, K. Stettiger
University of Kiel, Special Research Project 213, 24118 Kiel, Germany

SCINNA, an adaption of the Ocean General Circulation Model, based on the Primitive Equations, with conservation of mass, momentum, energy, heat and salt, and IMOC, an Intermediate Geostrophic

Teilprojekt B4:

NUMERISCHE MODELLE VON PALÄOKLIMA, PALÄOOZEANOGRAPHIE

UND SEDIMENTATION

Coupling to sedimentation: a newly developed sedimentation/erosion model which takes as input the velocity and tracer fields produced by SCINNA and IMOC. In this model, sediments are supplied from the continental margins and the sea surface. Additionally, sediments are allowed to resuspend again, taking the possibility of stepwise transport.

Kurzfassungen

Numerous experiments have revealed a very high sensitivity of the Northern North Atlantic's circulation and tracer field to even small changes in boundary conditions, which is reflected in the resulting sedimentation patterns. For the Late Quaternary, the circulation and sedimentation history have been reconstructed using the available sets of proxy-data from different time slices.

Die Kunst des 19. Jahrhunderts

Die Kunst des 19. Jahrhunderts ist eine Zeit, die von großen Veränderungen geprägt ist. Die Kunst des 19. Jahrhunderts ist eine Zeit, die von großen Veränderungen geprägt ist.

Die Kunst des 19. Jahrhunderts ist eine Zeit, die von großen Veränderungen geprägt ist.

Die Kunst des 19. Jahrhunderts ist eine Zeit, die von großen Veränderungen geprägt ist.

NUMERICAL MODELLING OF THE PALEO-CIRCULATION AND SEDIMENTATION IN THE NORTHERN NORTH ATLANTIC

B. J. Haupt, C. Schäfer-Neth, D. Seidov, K. Stattegger
University of Kiel, Special Research Project 313, 24118 Kiel, Germany

SCINNA, an adaption of the new Princeton Ocean General Circulation Model, based on the Primitive Equations with conservation of mass, momentum, energy, heat and salt, and IMOC, an Intermediate Geostrophic Circulation Model, are used to study the three-dimensional circulation of the Northern North Atlantic.

Coupling to sedimentation is achieved by SENNA, a newly developed sedimentation/erosion model which takes as input the velocity and tracer fields produced by SCINNA and IMOC. In this model, sediments are supplied from the continental margins and the sea surface. Additionally, sediments are allowed to resuspend again, thereby offering the possibility of stepwise transport.

Numerous experiments have revealed a very high sensitivity of the Northern North Atlantic's circulation and tracer field to even small changes in boundary conditions, which is reflected in the resulting sedimentation patterns. For the Late Quaternary, the circulation and sedimentation history have been reconstructed using the available sets of proxy-data from different time slices.

TOWARDS MODELING THE PALEOCIRCULATION AND
SEDIMENTATION OF THE NORTHERN NORTH ATLANTIC

B.J. Haupt, C. Schäfer-Neth, K. Stattegger
Sonderforschungsbereich 313 der Universität
Kiel

Models: For studying the 3-dimensional circulation of the Northern North Atlantic, MOM (Modular Ocean Model), the successor of the well-known Princeton Ocean General Circulation Model is used. This model is based on the Primitive Equations including conservation of mass, heat, salt, and momentum. High resolution (1 degree zonal, 0.5 degrees meridional, 8 levels vertical) allows realistic representation of topography. Coupling to sedimentation is achieved by a model containing sediment transport equations which takes the velocity field produced by MOM as input. In this model, sediments can be supplied from the continental margins and the sea surface.

Sensitivity studies: First, the model's response to various modern forcing data has been tested: wind (Hellerman & Rosenstein, MPI Hamburg T21 model results), ice cover (CLIMAP), and thermohaline forcing (Levitus).

Selected time slices: Based on the available proxy-data ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$), the ocean's circulation has been modeled for selected Late Quaternary time slices, with emphasis on the Last Glacial Maximum (18000 bp). Taking sedimentation rates from core data, sediment fluxes with resulting deposition/erosion patterns are computed to reconstruct the history of the sediment fill between time slices.

Cold Surface Ocean Ventilation and Its Effect on Atmospheric CO₂

ROBIN S. KEIR

GEOMAR, Forschungszentrum für Marine Geowissenschaften an der Christian-Albrechts-Universität zu Kiel, Germany

The potential for greater air-sea exchange rates in the northern Atlantic to decrease atmospheric CO₂ during the ice ages is examined using a simple model of the solubility pump. This potential is shown to depend on whether the modern ocean's region of sinking cold water is reequilibrating with atmospheric CO₂ at a rate comparable to the poleward transport of warm surface water. If this is the case, it is possible that greater ice age polar ventilation may have produced as much as 60% of the decrease observed in ice cores. In this scenario, the cold surface water CO₂ partial pressure does not covary with the atmosphere but instead would remain approximately constant.

INTRODUCTION

Most of the explanations of the lower ice age atmospheric CO₂ content have focused on either the "biological pump" (i.e., net carbon production versus upwelling flux) or "alkalinity mechanisms" in which a shift of dissolved inorganic carbon from intermediate to deep water occurs [Broecker, 1982; Knox and McElroy, 1984; Sarmiento and Toggweiler, 1984; Siegenthaler and Wenk, 1984; Boyle, 1988]. Both of these general theories have deficiencies. For example, in order to decrease the atmospheric CO₂ 80 ppm, carbon pump mechanisms increase oxygen consumption in the deep sea to the point that a substantial volume would become nearly anoxic [Ennever and McElroy, 1985; Toggweiler and Sarmiento, 1985; Keir, 1988], while alkalinity mechanisms would require a much greater vertical shift in nutrient proxies such as $\delta^{13}\text{C}$ and Cd/Ca in foraminifera than is observed. In these considerations, the role of CO₂ solubility has largely been discounted, because the estimated 1.5° to 2°C temperature decrease in overall surface ocean temperature would not decrease atmospheric CO₂ more than about 20 ppm and about half of this decrease would be counteracted by the increased salinity of the glacial ocean [Broecker, 1982]. However, dynamical considerations concerning the "solubility pump" have largely been ignored in this appraisal. Here the question of whether polar ventilation may be playing a role in controlling Pleistocene atmospheric CO₂ concentration is examined.

In the present ocean, well-ventilated warm surface waters flow northward in the Atlantic, lose heat, and eventually sink in the subpolar North Atlantic and in the Greenland and Labrador seas. Along the flow path, the total dissolved inorganic carbon concentration of the water increases as the CO₂ solubility increases (Figure 1; see also Broecker and Peng [1992]), and therefore the total CO₂ of the northern Atlantic surface waters is greater than in low latitudes. This overall process has been termed the "solubility pump" by Volk and Hoffert [1985] because it tends to maintain a constant total CO₂ gradient between the warm water and the polar cold water downstream. This in turn contributes to the vertical total CO₂ gradient because of the thermohaline circulation.

In this paper, a two-box model of the ocean surface is used to examine whether changes in the solubility pump could substantially contribute to the ice age atmospheric CO₂ decrease. Of particular interest is the sensitivity of atmospheric CO₂ concentration to increased ventilation of poleward transported, cooled surface waters prior to sinking. An increase in ventilation of high-latitude waters could be caused either by an increase in the gas exchange flux as a result of greater wind speeds or by an increase in the surface area of the sinking, cold water mass. Both of these increases appear possible for the last glacial maximum, the former being indicated by increased dust and aerosol concentrations in the continental ice cores [Hammer et al., 1985; De Angelis et al., 1987]. The CLIMAP [1981] reconstruction of ice age sea surface temperature suggests that warm surface ocean temperature was little changed, while the areal extent of cold temperature water expanded. In the North Atlantic, it appears that sea ice was well north of the polar front, and the ocean between about 45° and 60°N was a cold gyre which was largely free of ice [Ruddiman and McIntyre, 1981]. If so, the area of open water with temperatures less than 5°C would have been considerably greater during the ice age than in the modern ocean (Figure 2). It may be that the northern Atlantic was not a source of deep water during the ice age, but it appears that sinking to middepths (1600 m) did occur [Boyle and Keigwin, 1987], although perhaps at a slower rate than the present production of North Atlantic Deep Water.

MODEL DESCRIPTION

The overall modelling approach is similar to that of Volk and Liu [1988] in their study of CO₂ disequilibrium patterns in the surface ocean, which is considered here as a simple warm-cold two-box system with poleward surface transport (Figure 3). The deep ocean is treated as an external source that is supplied only to the warm box (1) with a fixed total CO₂ concentration Σ_0 . The source concentration represents the net effect of low-latitude upwelling and biological production of both organic carbon and calcium carbonate. The alkalinity that results from these processes is assumed to be constant throughout the surface ocean. Part of the source (U_2) is transported to the cold box (2), and part (U_1) simply downwells from the warm box without cooling.

The model is a simplification of three-box whole ocean models previously used to investigate the "polar nutrient" hypothesis [Knox and McElroy, 1984; Sarmiento and

THE EFFECT OF VERTICAL NUTRIENT
REDISTRIBUTION ON SURFACE OCEAN $\delta^{13}\text{C}$

Robin S. Keir

GEOMAR, Forschungszentrum für Marine Geowissenschaften
an der Christian-Albrechts-Universität zu Kiel,
Kiel, Germany

Abstract. Processes that shift nutrients from mid to lower ocean depths may or may not increase the ocean's vertical carbon pump. Redistribution of $\delta^{13}\text{C}$ produced by these processes is compared in two box models: a vertical three-box ocean and a thirteen-box ocean. In the former there is no $\delta^{13}\text{C}$ fractionation laterally between surface waters, and the ocean nutrient and $\delta^{13}\text{C}$ distributions are linearly correlated. This correlation is not changed when these tracers become redistributed, and if the model surface ocean is nutrient limited, the surface $\delta^{13}\text{C}$ cannot change. In the 13-box ocean there is a transfer of negative $\delta^{13}\text{C}$ from the cold surface water through the atmosphere into the warm ocean. Its $\delta^{13}\text{C}$ is therefore lower than it would be as a result of the carbon pump by itself. If a middepth nutrient depletion occurs because of lower nutrients in Antarctic waters, the warm surface $\delta^{13}\text{C}$ increases. If the vertical nutrient shift occurs because of ocean circulation or biological recycling changes, the warm surface water $\delta^{13}\text{C}$ change depends on the ratio of its vertical CO_2 fluxes, i.e., exchange of atmospheric CO_2 versus upwelling total CO_2 and net biological production. If this ratio remains about the same, then little change occurs in surface $\delta^{13}\text{C}$, and the $\delta^{13}\text{C}$ of Pacific deep water decreases about 0.3‰. In this case, no change in the average ocean $\delta^{13}\text{C}$ is required to explain observations from sediment data. This would imply that the ice age land biota carbon mass was about the same as that of today. The vertical CO_2 flux ratio could be an important consideration if greater wind-driven upwelling is a factor in the nutrient redistribution.

INTRODUCTION

Cd/Ca and $\delta^{13}\text{C}$ ratios in benthic foraminifera suggest that lower nutrient concentrations existed at intermediate depths in the glacial North Atlantic Ocean [Boyle and Keigwin, 1987; Oppo and Fairbanks, 1987; Zahn et al., 1987]. It is not yet certain whether this decrease was widespread throughout middepths in the ocean globally, as there are conflicting interpretations from $\delta^{13}\text{C}$ measurements made on Pacific sediments [Duplessy et al., 1988; Mix et al., 1991]. There are several mechanisms that could have caused a nutrient shift; some of them also reduce the atmospheric CO_2 and increase the difference between surface and deep ocean $\delta^{13}\text{C}$ [Boyle, 1988; Keir, 1988; Lyle and Pisias, 1990]. However, the various scenarios do not produce this increase in the same way: in some cases the $\delta^{13}\text{C}$ gradient increases mostly by an increase in surface ocean $\delta^{13}\text{C}$, and in others it increases mostly by a decrease in deep water $\delta^{13}\text{C}$. Each of these possibilities has a different implication concerning the ice age terrestrial biosphere, and therefore the question of how the different processes cause the vertical $\delta^{13}\text{C}$ distribution to change is examined here using two ocean box models. The results indicate that the ratio of upwelling total CO_2 to gas exchange flux could be an important consideration for the surface $\delta^{13}\text{C}$ change, particularly since it appears that greater average wind speeds drove a greater glacial ocean upwelling.

The earliest explanations for the ice age decrease in atmospheric CO_2 [Delmas et al., 1980; Neftel et al., 1982] were based on an increase in the ocean carbon pump efficiency, due either to a greater glacial ocean nutrient inventory, greater C/P ratio in the plankton, or a more efficient utilization of nutrients in the polar regions [Broecker, 1982; Knox and McElroy, 1984; Sarmiento and Toggweiler, 1984; Siegenthaler and Wenk, 1984]. Geochemical models of these processes produce an increase in the surface ocean $\delta^{13}\text{C}$ of about 0.5‰ but little change in the deep ocean $\delta^{13}\text{C}$ [Broecker and Peng, 1984; Berger and Keir, 1984; Ennever and McElroy, 1985; Toggweiler and Sarmiento, 1985; Wenk and

Copyright 1991
by the American Geophysical Union.

Paper number 91GB01913.
0886-6236/91/91GB-01913\$10.00

ON THE LATE PLEISTOCENE OCEAN GEOCHEMISTRY AND CIRCULATION

Robin S. Keir

Scripps Institution of Oceanography, University of California,
San Diego, La Jolla

Abstract. A box model of the atmosphere and ocean was developed to investigate how geochemical distributions extant during the late Pleistocene may have come about. The model simulates the regional distribution of calcium carbonate dissolution as well as the chemical oceanography and atmospheric CO_2 , $\delta^{13}\text{C}$, and radiocarbon. If the downward biological flux of particulate carbon increases by a factor of 2 to 3 in the Antarctic and if this increase is combined with a relative increase of the Atlantic sector Antarctic Bottom Water (AABW) versus North Atlantic Deep Water (NADW) source ratio from 1:3 to about 2:1, then the model predicts several changes that seem to be recorded in the sedimentary record, as follows: (1) A global redistribution of nutrients and ^{12}C from the intermediate to deep water takes place with the Atlantic intermediate water phosphate decreasing $0.6 \mu\text{mole kg}^{-1}$ and the $\delta^{13}\text{C}$ increasing 0.3 to 0.5‰ . (2) The dissolved oxygen level of the deep sea is reduced from an average of about 180 to $70 \mu\text{mole kg}^{-1}$, but the intermediate water oxygen declines only a small amount. (3) The decrease in intermediate water nutrient concentration results in lower average organic carbon and calcium carbonate production in the warm surface ocean. (4) The atmospheric CO_2 decreases by 90 to 110 ppm . (5) Initially, a global increase in calcium carbonate dissolution occurs, which is followed by a relaxation toward better preservation than exists for the present ocean. In the model in this paper the reduction of NADW by itself does not produce these effects. Rather, the nutrient decrease that does occur is found mostly in North Pacific intermediate water, and the model atmospheric CO_2 decrease is only 10 to 30 ppm . It is

observed that 92% of the atmospheric CO_2 change takes place according to a 200 -year time constant in the model. This corresponds to the response time of the upper ocean and atmosphere to a change in the stationary state atmospheric P_{CO_2} . Thus, according to this model, the time lag between the nutrient-based cause and the atmospheric CO_2 response is not expected to be particularly large.

1. INTRODUCTION

During the Pleistocene Epoch, climate on the earth's surface has been characterized by a rhythmic expansion and contraction of the polar ice sheets, with the extrema often referred to as "glacial" or "interglacial." The climate oscillation appears to be a nonlinear response to variation of the orbital configuration of the Earth about the Sun [Hays *et al.*, 1976; Imbrie and Imbrie, 1980]. Analysis of the CO_2 concentration of air trapped in polar ice has indicated that the atmospheric CO_2 partial pressure was about 30% less during the last (Wisconsin) glacial than the preindustrial present [Delmas *et al.*, 1980; Neftel *et al.*, 1982; Stauffer *et al.*, 1984]. The results from the Vostok Antarctic core suggest that the rise and fall of the atmospheric CO_2 is approximately coincident with that of ice volume [Barnola *et al.*, 1987].

In addition to the ice core data, marine sedimentary records of $^{13}\text{C}/^{12}\text{C}$, Cd/Ca and calcium carbonate dissolution in the late Pleistocene ocean provide the potential means for reconstructing how the ocean geochemistry and circulation varied during this time and what their relationship to the climate has been. Toward this goal, a hierarchical series of compartment models of the ocean and atmospheric geochemical system have been employed to investigate the effects of various hypotheses, beginning with Broecker's [1982a, b] suggestion of an increased ocean nutrient inventory during the glacial. Alternative hypotheses enhance the particulate carbon pump relative to the vertical circulation by

STRÖMUNGSMUSTER IM NORDATLANTIK, REZENT UND LETZTE MAXIMALVEREISUNG: ERSTE ERGEBNISSE MIT DEM SCINNA-MODELL (TP B4)

Schäfer-Neth, C. & Haupt, B. J., Stattegger, K.

Zur Untersuchung der Sensibilität und Zirkulation des nördlichen Nordatlantiks wird SCINNA eingesetzt, eine erweiterte Version des neuen Princeton OGCMs, MOM. Dieses prognostische Modell enthält in der Form der Primitiven Gleichungen die Erhaltung von Masse, Wärme, Salz und Impuls. Die Topographie ist durch die Auflösung von zonal 1 Grad, meridional 1/2 Grad und 8 Schichten in der Vertikalen realistisch wiedergegeben.

Die Verbindung zur Sedimentation besteht in SENNA, einem Sedimenttransportgleichungs-Modell, das basierend auf dem dreidimensionalen Geschwindigkeitsfeld aus SCINNA und der Vorgabe von Sedimentquellen an den Kontinentalrändern bzw. der Meeresoberfläche die Sedimentation und Erosion im nördlichen Nordatlantik modelliert.

INTERMEDIATE MODEL FOR LARGE SCALE OCEAN CIRCULATION STUDIES

D.G. SEIDOV

(Present Address: Geological-Paleontological Institute, Kiel University, Olshausenstr. 40, W - 2300 Kiel, Germany)

ABSTRACT

Design and purposes of an intermediate model are discussed along with fundamentals of the model and test numerical experiments. The main goal of the use of the model are reconstructions of the schemes of the ocean paleocirculation. For this problem numerical effectiveness is the key factor. Parameterization of the side Ekman boundary layers was introduced to enable the use of geostrophy for calculating baroclinic velocity. Preliminary numerical experiments with simple basin geometry and idealized forcing aimed at qualitative comparison with primitive equation models were carried out. The results of the experiments are discussed in context of the applicability of intermediate models for studying large-scale ocean dynamics.

TOWARD A BETTER UNDERSTANDING OF THE NORTH ATLANTIC RESPONSE TO THE MELT-WATER EVENT NEAR 13.6 KA - A NUMERICAL OCEAN CIRCULATION MODEL

D. Seidov (P.P. Shirshov Institute of Oceanology, Moscow, Russia, and Geological-Paleontological Institute, Kiel, Germany), I. Yushina, M. Samnthein, and K. Statteger

The ocean response to local changes in winds and thermohaline conditions of the surface is not yet well understood. The rates and scales of changes of the ocean currents and the thermohaline structure are of primary interest for identifying the spreading of low-salinity waters. Therefore, we tested a paleoreconstruction of a major meltwater event subsequent to the Last Glacial Maximum (LGM). The $\delta^{18}\text{O}$ maps reveal steep salinity gradients formed in subpolar regions of the eastern North Atlantic at that time. We modelled the North Atlantic ocean large-scale circulation using model winds for 18 ka BP simulated by Lautenschlager and Herterich in the framework of T21 atmospheric GCM. Special attention was paid to shifts of the polar front, linked to strong melt water injection 13,600 years ago. The main interest was directed to the problem of possible switches of water overturn process and its connection to the changes in circulation in the subtropical North Atlantic. Preliminary results of our numerical study indicate noticeable changes in the position of the isopycnal outcrops, which mark the thermohaline fronts. Changes in the overall currents system also suggest, in harmony with the results of proxy data reconstructions, that variation of the surface salinity in subpolar eastern North Atlantic might have triggered a switch in the Atlantic salinity conveyor.

MAGMATIC EVOLUTION OF THE URAL PALEO OCEAN

I. Seravkin (Institute of Geology, Bashkir Scientific Center, Ural Division, Academy of Sciences, Ufa, Russia)

The Paleozoic ocean in the Urals is indicated by geologic formations: 1) shelf and bathyal complexes of the East-European plate margin preserved at the western slope of the Ural; 2) fragments of the ocean-type crust (ophiolite triad) occurring within the melange of the suture zone and major thrusts; 3) arc volcanogenic formations of the Magnitogorsk belt; 4) volcano-plutonic formations of continental-marginal belts in the eastern zones. All these units form an asymmetrical magmatic, facial and metallogenic zonation that shows both western passive and eastern active continental margins corresponding to D_{2-3} to be present.

The evolution of chemical composition in volcanic rocks according to main and satellite elements (Rb, Sr, Ni, Cr, Co, Ti, Zr, REE, etc.) suggests the most complete development of J. Wilson's cycle. Splitting of the continent was accompanied by eruptions of trachibasalts (C-O) while spreading of the volcanic basin - by mass effusions of ocean-type tholeiites (O-S); development of submarine riftogenic structures - by contrast rhyolite-basaltic volcanism (S); subduction along the eastward dipping Benyoff zone - by arc volcanogenic formations of alkali-lime and shoshonite series (D_{2-3}); and collision - by volcano-plutonic subalkali and alkali-lime Andes-type belts (C_{1-2}) as well as intrusions of granite batholites (PZ_3).

Latitudinal variations in composition of synchronous riftogenic and arc volcanogenic complexes have been recognized. Facial zonation, approximate evaluation of rate under spreading and chemical behaviour of ancient versus

Mesozoic and Cenozoic Oceans

Kenneth J. Hsü
Editor

Geodynamics Series
Volume 15

NUMERICAL MODELLING OF THE OCEAN CIRCULATION AND PALEOCIRCULATION

D.G. Seidov

Shirshov's Institute of Oceanology, USSR Academy of Sciences, Krasikova, 23, 117 218 Moscow, USSR

Abstract. A numerical model of the ocean circulation has been developed and applied to the problem of paleo-circulation reconstruction. The physical basis of the model is presented as well as a sketch of the numerical approach as a method are discussed. The model has been tested in numerical experiments aimed to reproduce modern circulation and hydrology patterns. Then, the model has been used to reconstruct schemes of currents and hydrology of the Late Mesozoic and Cenozoic eras. The atmosphere has been assumed to be zonal, and continents drifted after the breakup of Pangaea as it is proposed by geodynamics. The results of the numerical experiments are discussed and major feedbacks are identified which regulate the climatic changes of the ocean.

Introduction

There has always been great interest among paleo-ecologists, paleoclimatologists and geologists in geologic history of the earth's climate and the paleoenvironment of the World ocean. However, paleogeography has operated mainly with currents reconstructed using indirect data, i.e. paleoecological data (e.g. Gordon, 1973; Westermann, 1980; Berggren and Hollister, 1974) or using analogies between modern and ancient circulations of the atmosphere (Parrish and Curtis, 1982). Although such reconstructions are helpful to some extent in paleo-geographical studies, they too often are arbitrary or inconsistent with hydrophysics. The data are unevenly distributed in time and space and generally insufficient for reconstructions of the global or large-scale current systems. The reconstructions themselves are not based on the laws of physical oceanography such as conservation of mass (i.e. the mass of water which flows into certain volume of fluid should be equal to the mass which flows out), hydrostatic stability, conservation of angular momentum, etc. The only study of the ocean paleo-circulation by physical methods has been carried out using a laboratory model (Luyendyk et al., 1972). We should also mention here a laboratory reconstructions performed by Lazarev (1950), although these were based on a fixed continental position approach. There is a lot of evidence now that continents move over the earth's surface. It is absolutely clear that for different position of continents there would be accompanying different resulting patterns of the ocean circulation. We are not going to discuss any

aspect of plate tectonics or geodynamics technique. We will simply deal with a hypothesis that the continents were situated in very different places than they are at present time. We will also use geodynamical reconstruction of previous continental configurations on the globe. Inferences from this hypothesis (using paleobio-geographical data and geological records) have already been exploited by some authors (Gordon, 1973; Kennet, 1977 and others; see for example Lisitsin, 1980). The role of continents may be easily seen from their present constraints on the ocean circulation. The earth's atmosphere generally is able to circulate around the globe since the air has no meridional borders on its circumzonal way. The ocean currents evidently are in very different situation. There is only one circumglobal ocean current at present time, namely the West Wind Drift current. Meridional ocean boundaries produce most general features of the circulation such as subtropical anticyclones or subpolar cyclonic gyres. This major characteristic quality of the circulation patterns gave a basis for well known idealized theoretical studies (e.g. Stommel, 1948; Munk, 1950; Veronis, 1966 and others). In these studies rectangular basins with flat bottoms and with homogeneous fluid approximations were used as conceptual models. The only real geophysical features were rotation of the earth, its spherical geometry (parameterized by meridional change of the Coriolis parameter), and the wind stress which itself was highly idealized and even had been introduced into the model as a zonal field (e.g. Stommel, 1984). Significant success of such enterprises may be interpreted only as a proof of the priority of the meridional boundaries plus differential rotation (or spherical geometry) in formation of the ocean circulation patterns. It should be stressed, however, that specific current systems are formed with different specific causes, and especially under effects of the specific geometry of different oceans.

At the same time one has available the possibility of reconstructing the ocean circulation of past geologic periods using numerical simulation techniques. This possibility emerges from certain encouraging results achieved in numerical studies of present ocean circulation. At least major features of global ocean circulation are reflected by these models in qualitative agreements with observations, or with existing images of present day circulation and hydrology patterns. If one raises not too rigorous demands and does not wait for detailed mapping